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VOLUME 9 **NOVEMBER-DECEMBER, 1959** **NUMBER 6**

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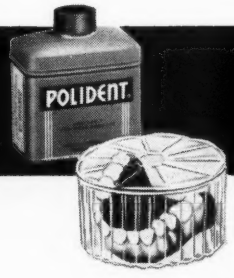

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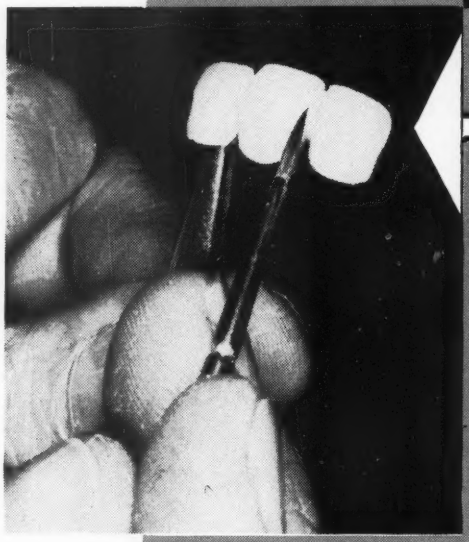

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THE JOURNAL OF
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THROUGH THE EYES OF THE EDITOR

Arthur L. Roberts discusses many of the current concepts in complete denture service. He gives a brief summary of the early history of each of the various phases of denture construction as a background for his analysis of the current status of each component of the total service. This emphasizes the tremendous amount of progress that has been made in the last 100 years. Progress sometimes appears to be slow, but when the science of prosthodontics is examined in this manner, it is shown to be quite rapid. Many of the problems he discusses must be classified as "controversial" in so far as their possible solutions are concerned. His analysis seems to represent a good cross section of the current status of prosthodontics, however, and he has pointed the way to further improvements.

John P. Frush and Roland D. Fisher describe three educational phases in the practical application of the dentogenic concept of esthetics. These are the education of the dentist, the education of the laboratory technician, and the education of the patient. The dentist must take the lead in this work and educate both the laboratory technician and the patient. Since the laboratory technician does not see the patient, the dentist must first supply the technician with the necessary information and *then modify* the basic tooth positions to fit the individual requirements of the patient at the dental chair. Otherwise, the tooth arrangements will tend to become stereotyped. The dentist must also educate the patient to accept the tooth arrangement which is best for him. Many patients have preconceived ideas regarding the way they want their teeth to look. Too often these ideas are incorrect and, if applied, would be detrimental to the appearance of the patient or the teeth, or both. The authors suggest a means for educating patients so they will understand the objectives of esthetics in dentures.

Richard H. Kingery discusses centric relation and centric occlusion. He suggests that it is necessary for the dentist to have a mental image or concept of the objectives of centric relation and centric occlusion. This seems to be correct if one is to avoid the confusion which could result from the apparently contradictory techniques and philosophies of occlusion. When there is complete understanding, many of the apparent contradictions disappear.

Daniel Isaacson reports his experiments to determine the possible relationship between the age and sex of the patient and the angulation of the condyle path. The study was carried out on 36 patients by means of a Gnathograph. The results indicated that there is no correlation with age or sex and that the condyle paths of adults do not change significantly.

Charles A. Brekke discusses hinge axes as they relate to jaw function. Much of his discussion is of a controversial nature, since he considers the various elements of the problem separately. Regardless of the shape of the individual condyles and regardless of asymmetry of the mandible or the "dissimilar planes of orientation" of the condyles, the mandible must

move as a single body when it is moved. When the mandible moves in a hingelike manner, the *entire* mandible can rotate only about a single axis (assuming for illustration that a perfect mechanical axis does exist in an anatomic structure). If the two condyles did not lie in the same horizontal plane or in the same frontal plane, the "transverse" axis would *not* be perpendicular to the sagittal plane. Thus, the "hinge" rotation would be in the off-sagittal plane in the head. In these instances, the casts must not be mounted *level* in the articulator if the axis of the articulator is *level*. Instead, the casts should be mounted asymmetrically in the articulator, unless the instrument itself can be adjusted so its condylar elements have the same asymmetry as the condyles in the head. The same results can be achieved by either procedure. One way, the axis (with or without a shaft between the condylar mechanisms) is oriented asymmetrically with the bench top, and the casts are oriented level with the bench top. The other way, the axis of the instrument is oriented level with the bench top, and the casts are oriented asymmetrically in relation to it. The important consideration seems to be that an accurate transfer of the relations existing in the head be made to either type of instrument. Either the articulator must be adjusted to the asymmetry (in one type of instrument) or the casts must be mounted to reproduce the asymmetry (in the other type of instrument).

Thomas E. J. Shanahan and Alexander Leff report their experiments done to compare the opening and closing movements of the mandible with the opening and closing movements of an articulator. Records of the movement in the sagittal plane were made with no control of the mandible other than the neuromuscular control. These records showed considerable variation. As could be expected, both the arcs of opening and closing of the articulator followed identical paths when the articulator was held in the hinge position. It would be interesting to see if it is possible to control the articulator movement by hand to retrace the movement made by the mandible. These experiments seem to emphasize the importance of the neuromuscular system in the control of mandibular movement.

Irving M. Sheppard compares the effectiveness of various means for studying jaw movements in function and reports on the use of serial roentgenograms for this purpose. The method used has advantages over some other techniques, but it also has some limitations. The results indicate that there is considerable variation in jaw movement and tooth contact, even with the same patient and same test food. The speed of any one closing stroke varied considerably, also. This work seems to support the concept that the major controlling factor is the neuromuscular system.

Anthony K. Kaires reports his studies of occlusal contacts made during function by denture teeth. Tests were made on three sets of dentures for the same patient. Three types of tooth forms were used. The monoplane teeth were arranged with zero-degree condylar and incisal guidances. The condylar guidances were adjusted by means of interocclusal records for the arrangement of the cusp teeth. The contacts were detected by an electronic circuit whenever metallic points on surfaces built onto the teeth would touch. As would be expected, the tooth contacts during function were different from those produced on the articulator by rubbing the teeth together. There were more contacts on the balancing side than on the working side. This might be explained by the depression of the dentures on the working side and a *tendency* for the balancing side to tip away from the supporting ridges.

R. Wheeler Haines and Sidney G. Barrett discuss the anatomy of the mouth in the mandibular molar region. They illustrate the relationships of the various structures by a series of excellent drawings. Their interpretations differ from those of some other authors, but this may be due, in part, to some slight differences in terminology. They recognize a "retromolar pad" and a "pear-shaped pad" as being two different structures, while most American dentists consider them as the same structure with two different names. Probably, the "pear-shaped pad," as they describe it, is a part of what we call the retromolar pad.

Otis M. Johnson discussed the factors related to the formation of torus palatinus and torus mandibularis. He concluded that alterations in the direction and magnitude of occlusal forces contribute to the development of tori. He suggested that their formation is a type of defense mechanism. This possibility should be investigated further.

Joseph S. Landa begins a series of articles in which he explores the causes of difficulties with dentures and points out the means for eliminating the difficulties. In Part I, he dis-

cusses the characteristics of the oral mucosa and the pathologic changes which may occur under dentures. He emphasizes the importance of an accurate diagnosis of "sore spots" before adjustments are made and describes his technique for making the diagnosis and treatment.

Harry R. Skurnik describes his method for planning and carrying out the procedures involved in occlusal rehabilitation. The plan is orderly and logical, and if it is carefully followed it should produce excellent results. He points out the indications for many different types of procedures and emphasizes the importance of considering the possibilities of each of them at the proper time in diagnosis and treatment.

S. Charles Brecker urges conservatism in occlusal rehabilitation. He suggests that not all occlusal situations can be made to conform to a mathematical ideal. He describes ten difficult occlusal conditions which require modifications of the so-called ideal occlusion. An incorrect treatment plan will lead to failure in these situations, even if the technical work is faultless. He emphasizes the importance of an adequate interocclusal clearance and feels that this is more critical than the development of "balanced occlusion." This philosophy is in agreement with that of many others, and it is physiologically sound.

Sumter S. Arnim urges that good judgment be used in cavity preparation, with the objective of protecting the health of the dental pulp. He suggests that certain cavity preparations be modified to meet the requirements of each individual tooth. Not all teeth are exactly alike, and the diseased areas are not always in the same place on all teeth. It seems logical to make individual variations in cavity preparations to meet the individual conditions in each tooth. Any operative procedure should have as its major objective the protection of the living parts of the teeth.

Takao Fusayama discusses the various factors involved in making accurate castings. The procedures he suggests for different types of castings seem to follow the basic principles he discusses. The techniques are not difficult, but they must be carried out carefully if the best results are to be obtained.

François Ackermann discusses the design of subperiosteal implants for the support of complete lower dentures and describes some of the technical procedures involved. He points out the importance of correctly made "preoperative" dentures and emphasizes the importance of the proper distribution of occlusal forces. Balanced occlusion should be considered as an essential part of implant denture techniques.

Max M. Weinreb and M. Bogen describe their one-day technique for making and inserting the substructures for denture implants. The procedure involves extremely close cooperation between the prosthodontist, the oral surgeon, and the technicians who fabricate the substructure. They see many advantages in the procedure, including a reduction of the time interval between the beginning of the operation and the insertion of the superstructure.

Henry K. Yaggi describes a simple technique for making a prosthetic appliance to maintain radioactive needles in the desired positions for treating malignancies of the oral cavity. By this means the amount of radiation can be controlled, and the patient is not subjected to an additional operation for the placement of the needles.

—Carl O. Boucher

COMPLETE DENTURES

PRESENT-DAY CONCEPTS IN COMPLETE DENTURE SERVICE

ARTHUR L. ROBERTS, D.D.S.
Aurora, Ill.

THE FIRST ARTIFICIAL teeth were made by a relatively isolated people in the Italian hills, the Etruscans, in about 500 B.C. The Etruscans were probably the first prosthodontists. Relics of their work may be seen in a Florentine museum.

At about this same time, Hippocrates lived in Greece. He devoted thirty-two paragraphs is his compendium to the human dentition and dental disease, but he did not mention prosthetic dentistry. The *Ebers Papyrus,* which told of medical practices in ancient Egypt, included descriptions of many dental diseases and their treatment but nothing about replacement of lost natural teeth with artificial substitutes. A lack of prosthodontic knowledge also characterized the civilizations of ancient Babylon, Sumeria, China, India, and Rome.[1] It is interesting to note that all of these civilizations had one common philosophy. It was considered vulgar and degrading to use the hands to create anything but art objects. To make useful things was an occupation fit only for slaves. This philosophy certainly eliminated most prosthodontics.

By the beginning of the Christian era, the Romans had borrowed some of the Etruscan dental techniques. Artificial teeth were probably fairly common among the Roman upper classes. These prostheses were supplied by slave artisans who could neither read nor write and, therefore, did not record their methods. Dental restorations were made solely for cosmetic reasons. Celsus, the Roman physician, wrote about many dental diseases but said nothing about prosthodontics, just as a medical writer of today would probably not describe wigs, earrings, or costume jewelry. With the fall of the Roman empire, whatever dental skills that had been developed shared the fate of all Roman culture, and for seventeen hundred years, through the Dark Ages and the Middle Ages in Europe, dentistry stood still.

Modern dentistry dates from the time of Pierre Fauchard, in France, about 1750. At that time, however, complete artificial dentures were rarely made and were available only to the wealthy. Complete dentures were rare until about 1850. Two events in the United States made artificial denture service possible for the masses. They were the discovery of anesthesia and the development of vulcanization of

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rubber. Anesthesia made tooth removal painless. Vulcanite was an inexpensive material for denture bases. The result was the wholesale extraction of teeth and their replacement with dentures.

From this short historical review, it can be seen that complete denture service is only about one hundred years old. Living as we do in a relatively newborn society, it is apparent that everything we do, in prosthodontics, in our daily work, is based upon concepts and methods which have flashed very recently upon the screen of history. Is it any wonder that prosthodontic thinking exhibits the many conflicts and dilemmas that characterize all youthful growth and development? We are still feeling our childlike way, and we have much to learn!

It is understandable that we should be impatient to quiet these conflicts. At first glance, it would seem wise for a group of students to determine by majority vote how to render the best prosthodontic service and to publish the technique for the guidance of the "average dental practitioner." The danger in this plan lies in the common human weakness of *believing* the written word. Blind reliance on "accepted practice," instead of on judgment based upon knowledge, has more often retarded study rather than stimulated it.

Complete denture service may be divided into five related parts. They are (1) examination and treatment plan, (2) impression making, (3) maxillomandibular position records, (4) denture form and facial appearance, and (5) postoperative care.

EXAMINATION AND TREATMENT PLAN

People who have lost all of their natural teeth are dental cripples. As such, they deserve sympathy, understanding, and skill. Successful prosthodontic treatment begins long before denture construction is started. It begins with a plan based upon an examination of and a consultation with the patient. The plan has two objectives: (1) to study all aspects of the problem (biologic, mechanical, esthetic, and psychologic) with a view to correcting unfavorable factors which will respond to treatment, and (2) to obtain an understanding with the patient in order to secure the patient's cooperation in the solution of his problem.

The importance of this phase of denture service has been recognized for a long time.[2] As prosthodontics gains recognition as a branch of the healing art, thorough examination and treatment plan are being given the emphasis they deserve. Successful treatment depends upon treatment of the patient as an individual and not as a mechanical problem only. Modern dentists are as much concerned with the physiologic, pathologic, psychologic, and nutritional aspects of prosthodontic service as they are with the physics and chemistry of the materials employed.

When making the examination, attention is first directed to those aspects which, if abnormal, may be expected to respond favorably to treatment. These are: (1) *Deformations of the ridges and unfavorably placed tissue attachments* requiring surgery. (2) *Abnormalities of the mucosal base.* Some mucosal abnormalities may be part of a systemic condition which requires medical treatment. Some may be distortions caused by the pressure of ill-fitting appliances. If this be the case, the treatment is simple but imperative; the offending appliances must be removed until the tissue is normal.[3] (3) *Abnormalities of the temporomandibular joint.* Malfunc-

tion of this joint, with condylar displacement, may be the result of malocclusions or loss of muscle tone. Arthritic changes may be present. If correctible, treatment of the joint must precede the making of the dentures. Sears'[4] statement that "occlusal equilibration should follow and not precede mandibular equilibration" makes sense.

Those factors which are not correctible are noted. Such obstacles must be met by compromise based upon judgment. Included among them are the almost completely resorbed ridges, deformations of the palatal form, abnormal tongue size, abnormal functional tongue habits, aberrations in the character and amount of saliva, or an unfavorable maxillary to mandibular jaw relationship.

The apparent tonus of the oral musculature is important. Many elderly patients have poor muscle tone and very little residual ridge tissue. The lower the muscle tone, the greater the size of the basal seats of the dentures may be. Maximum coverage helps patients with badly resorbed ridges, because more favorable external denture forms may be developed.

Preliminary open mouth alginate impressions are helpful in diagnosis. Quick-setting plaster of Paris casts may be poured and mounted on a simple articulator at an approximately correct vertical relationship. Study of the result aids in visualizing the design of the contemplated prostheses, particularly regarding the selection of the type of posterior chewing units.

Pre-extraction casts are essential if any natural teeth are still present in the mouth. These casts may be mounted on an articulator, using plaster interocclusal records of the apparent mandibular rest position. There is no better way of perpetuating the correct interocclusal distance. The artificial teeth should be placed in similar positions to those occupied by the preceding natural teeth with correction of obvious malocclusions and improper postions resulting from drifting.

It is important that the patient understand his problem. Many difficulties must be met and overcome by conscious effort on the part of the patient. DeVan[5] has stated, "The dentist must meet the mind of the patient before he can successfully meet the mouth of the patient." I have never successfully made artificial dentures for someone whom I disliked or who did not like me.

Many years ago, House classified patients into four groups: philosophic, exacting, hysterical, and indifferent. Subjectively, this classification still stands as a good one. As representatives of the health service, however, one might wonder whether or not it is within our province to change some of these people from one class to another by skillful analysis and by "meeting the mind of the patient."

SPECIFICATIONS FOR DENTURES

Satisfactory dentures have good retention. That is, they remain connected to the patient when the jaws are apart. This is most of the time.

Satisfactory dentures have good stability. That is, they do not rock or skid when the patient brings the lower teeth against the upper teeth as in chewing or swallowing

Satisfactory dentures aid in masticating and speaking. They maintain or improve facial appearance. Last, but not least, they defend and do not destroy the vital tissues with which they are in contact.

Three factors are concerned in meeting these specifications. They are (1) the way that the dentures are connected to the supporting tissues, (2) the way that the external form of the dentures fits the internal form of the oral cavity, and (3) the way that the dentures fit each other.

IMPRESSION MAKING

One of the very early methods of connecting artificial teeth to the patient was by a technique called "pivoting." Natural tooth roots were prepared for the reception of dowels which were part of the denture base. Later, maxillomandibular metallic springs, bent backward and attached to each denture, were employed to press the dentures apart from each other.

It is interesting to note the similarity between the old technique of pivoting and present-day efforts to fasten the denture to the patient by means of subperiosteal implants. By the older method, the denture rested upon natural tooth roots embedded in bone; the present method is to rest the denture upon metallic stumps which are projections from a subperiosteal implant. Those who have reported success with these implants claim that greater masticating pressures are possible by this method than are possible with dentures that rest upon a mucosal base. They point out, however, the necessity for building implants upon basal mandibular bone. Any residual alveolar bone contraindicates their use. This method of connecting dentures to the jaws deserves further study.

Today, the most commonly used method of connecting dentures to the patient is that of fitting the inside surfaces of the prostheses accurately to the residual alveolar ridges and palate. The physical forces employed are those of adhesion, cohesion, atmospheric pressure in the maxillary denture, with gravity added in the mandibular denture.

SPECIFICATIONS FOR ADEQUATE IMPRESSIONS

Three specifications apply to the making of adequate impressions for complete dentures[6]: (1) The form of the denture foundation (the oral tissue which must resist the pressures of occlusion) is recorded *without* distortion. (2) The outline of the basal seat (the entire area of coverage) is recorded as it is influenced by functional movement of lips, cheeks, and tongue. It is not sufficient to apply this specification to border tissues only. *Border molding does not begin and end with the denture edges but includes the entire denture form.* (3) Reliefs and dams are placed in strategic areas at the dentist's discretion.

An adequate maxillary impression would result from an imprint of the foundation tissues without distortion. Limitation of coverage and edge thickness are determined by functional movement of lips, cheeks, and soft palate. Tight contact of the base with tissue on a line determined by soft palate movement terminates the impression distally. Displaced tissue in this area must not overlie bone. If it did, the osseous base would be changed by the pressure. Instead, the displaced tissue in this area is supported by the palatal aponeurosis, a muscular structure not subject to resorptive change by pressure.

An adequate mandibular impression records the foundation, likewise, without distorting it. It exhibits maximal coverage of all ridge tissues which do not move when the patient speaks, chews, or moistens the lips with the tongue. In the case of a mandibular impression, especially, a prime objective is the development of an outline form and edge thickness which will provide a cast upon which an effective external denture form may be developed. This external denture form is such that the contacting structures, the tongue, lips, and cheeks, may be employed to steady the denture instead of to push or lift it from its base.

Extension of denture flanges is determined by (1) the position of border tissue attachments and their functional movements, (2) the tonus of the related tissues, and (3) the development of a denture external form which will be in harmony with the oral cavity's internal form.

The principle of recording the foundation tissues at rest and not distorted by pressure, when making impressions, seems basically correct. By avoiding such tissue distortion, subsequent tissue change will be minimized. Retention and stability of the denture will be enhanced and prolonged.

In 1869, George[7] wrote, "Plaster of Paris is an excellent impression making material because no pressure is required and the displacement of soft tissue is thus prevented." In 1886, Richardson[8] emphasized the advisability of making impressions with the tissues at rest, contending that "adhesion by contact" was a basic principle in obtaining retention.

In 1938, this idea was described and given much publicity by Page.[9] Prosthodontics owes much to Page and his collaborators. They demonstrated graphically how displaced tissue disturbs both retention and stability. It seems wrong for them to have contended, however, that the "mucostatic principle" was at variance with all other accepted impression-making methods. They might have more rightfully incorporated the idea into a more comprehensive and effective technique.

It is unfortunate that the value of Page's work was adversely affected by the commercialism accompanying it. His ideas were connected with the sale of a special type impression tray and the use of a metallic alloy for the denture base. The trays were of good design; the alloy was excellent. It is too bad that such valuable work revolved about sales of materials. This situation has been repeated many times in dental history. Similar instances occurred in Goodyear's development of vulcanite and in Taggart's work with the cast gold inlay. There are many others. This observation makes apparent the desirability of closer cooperation and understanding between all dental groups. The manufacturer, the technician, the hygienist, the assistant, the supply house, all have much at stake and have much to contribute. Many good things come from all of them. Closer understanding and cooperation will contribute much to future progress.

At variance with the "rest impression" idea is that of recording the shape of the supporting tissues while they are under occluding pressure. Such impressions must be made with the mouth closed. Those who favor this method call it "tissue placement" while those who do not favor it call it "tissue displacement." There is probably merit in both schools of thought; however, dentures are in occlusion only a very small part of the time, actually only during the act of swallowing. Most of the time, they are just lightly in contact with the mucosal base, the upper denture

being suspended from the tissue and not pressed upon it. Among patients who have worn dentures a long time, the most nearly normal tissues are found under appliances which have just a benign and comfortable fit. Dentures should fit the tissues at rest. Impressions should be made with this thought in mind.[10]

Possibly, somewhere between the two schools of thought, that is, pressure or nonpressure, there may be middle ground which employs the maximal advantages and minimal disadvantages of each. Boucher[11] has described such a reconciliation. With anatomic and functional factors as a basis, he described a mandibular denture impression technique which would place little or no pressure over the ridge crests but would offer intimate contact between the buccal flanges and the tissues covering the buccal shelves of the mandible.

RELIEFS AND DAMS

The most generally used relief is that placed on the area of the maxillary median raphe. In 1835, Chapin Harris[12] designed what he called an "air chamber plate," the air chamber being a depression in the surface projecting downward from the palatal surface. In 1840, Alfred Riggs[12] obtained a patent for a "chambered plate" which was of similar construction. This technique was received with great enthusiasm. A textbook published by the Academy of Dental Science in 1876 stated, "Years of constant use have proved the value of the cavity plate. It forms one of the greatest advances in prosthetic dentistry."

A remnant of this enthusiasm remains today, a hundred years later. It is still common practice to place huge "relief chambers" in maxillary dentures. Most such chambers are put in, arbitrarily, by laboratory technicians. As a result, in many instances, much palatal support is lost for the denture, with subsequent shifting of its position. It is habits such as this that I referred to earlier in this article, of blindly following "recommended" and "accepted" practices without the application of personal judgment based upon knowledge.

Relief, when necessary in the maxillary median area, is provided to avoid teetering of the denture when it is subjected to pressure on either side. The extent and volume of relief are determined by the difference in degree of displaceability of the ridge structures and those in the median area. If there is no difference, no relief is needed. In practice, if doubt exists as to the amount of relief indicated, the palatal part of the denture may be made a little thicker and the relief may be made on the finished denture with the aid of a disclosing wax. Then, following this correction, the denture thickness may be adjusted. Placement of excessive relief in dentures is not good practice.

Other areas of dentures may require relief, such as over the incisive papilla, over the mental foramina, or over thinly covered bony humps and bumps. This relief, also, is best done on the completed dentures by the use of a soft disclosing wax.

Two areas usually require the addition of dams: (1) the posterior palatal region of the maxillary denture and (2) the sublingual crescent of the mandibular denture. The dam (posterior palatal seal) in the maxillary denture is made by displacement of soft palatal tissue. The dam in the mandibular denture is made, *not*

by displacement, but by increasing the coverage of the floor of the mouth by thickening the denture edge.

The dam in the maxillary denture is placed to provide an air seal and tight contact with the movable palatal tissue when the denture shifts forward due to its use in incision. Here, again, the foundation is frequently weakened by allowing the technician to place this dam, arbitrarily, by scoring the cast from a point distal to the tuberosity to a similar point across the arch. Placement of the posterior palatal seal should be done with more care than this. The denture edge and dam should accurately follow the variable line of functional movement which may be seen by observing the palatal change in form when the patient is requested to attempt to force air from the nose with the nostrils held closed. The line varies in different individuals and is not always bilaterally symmetrical in the same individual. Placement of the distal termination of the maxillary denture and the accompanying dam should be done by the dentist, not by the technician.

The dam in the sublingual crescent area of the mandibular denture is made by thickening the edge and extending it distally to the point of tolerance. This tolerance varies greatly in different individuals. Some patients cannot tolerate the application of this dam at all. The reason for its use, when it can be used, is that a favorably inclined plane is thus provided on the denture from its edge to the lingual surfaces of the lower incisor teeth on which the undersurface of the tip of the tongue may be encouraged to rest. This tongue position is a great aid in providing retention for the denture. Another practical advantage is that the denture is strengthened in an area particularly susceptible to breakage.

Impressions are, therefore, the result of an imprint of the undistorted foundation form, plus what the muscular activity of the mouth does to its edges and form, plus what the dentist adds in the way of reliefs and dams. Impressions for dentures are made, not taken.

EXTERNAL DENTURE FORM

In 1800, Gardette,[13] having inserted dentures temporarily without the usual springs to hold them apart and in place, was surprised a short time later, when calling upon the patient to supply the springs, to find that the patient was able to retain both dentures perfectly without the springs. Gardette reported his experience, concluding that support of the dentures was by involuntary and instinctive contractions of the oral muscles. Apparently, Gardette was the first to note and record the idea that a compatible, harmonious external denture form was an important factor in retention.

When we think about the fit of artificial dentures, it is very easy to focus our attention entirely upon the way they fit the ridges and palate. This is important, but the *outside surfaces of the dentures should fit the patient, too.* If this fact were more generally realized, there would be a great and proper drop in the use of the many and various rebasing pastes and materials which are so promiscuously used to refit loose dentures by tightening them against the tissues. Tight shoes do not necessarily fit.

Development of external denture form has four objectives: (1) stabilization by harmonizing the palatal and flange form and edge thicknesses with the potential

denture space, which is bounded by the location and activity of the tongue, cheeks, and lips, (2) enhancement of the patient's appearance by providing lip support, (3) aiding in the placement of food, and (4) aiding in speech.

Dentures tend to be displaced during mastication if malocclusions are present, but mastication occurs a relatively small part of the time.

Dentures tend to be displaced by the tongue, cheeks, and lips when they are used as aids in expression or speech. This is a relatively great part of the time. By harmonizing denture form to its environment, displacement from this source will be minimized.

A basic concept of good denture form is one against which pressures on one side of the ridges by the tongue are equal with pressures on the other side by the lips and cheeks. Denture flanges should present planes favorably inclined to these structures so that the muscles may be employed to hold the maxillary denture up and the mandibular denture down. Fish[14] described these principles very well.

The maxillary denture can be supported advantageously by the tongue or dislodged by it. If the palatal arch is made too wide, too high, or even too smooth, and if no effort is made to copy the contour of the patient's palate as it was shaped with his natural teeth in place, stabilizing action by tongue action is difficult.

Another basic concept of denture form is that the artificial teeth should be placed as nearly as possible in the same positions which their natural predecessors occupied. Of course, corrections should be made of malocclusions due to drifting, elongation, and similar aberrations. The positions of the natural teeth were determined by the patient's individual, unchangeable growth and functional pattern. It is logical to perpetuate these relationships, with some compromises, when supplying artificial substitutes.

FACIAL APPEARANCE

Denture form influences facial form and the dynamics of facial expression, as Pound[15] and others have pointed out. Thus, it seems proper to comment upon denture esthetics when considering denture form.

When artificial teeth were first made of porcelain, they were called "mineral teeth" and were available in several sizes and shades.

Later, attempts were made to analyze each patient's need so far as size and shade were involved and then to arrange the upper front teeth on an arc which harmonized with the face form of the patient.

When the synthetic resins displaced vulcanite as a denture base material, naturalness of appearance took a great step forward. Next followed efforts to color the denture base to make it look like oral mucosa, in rather minute anatomic detail. Pound's[15] work along this line and his emphasis upon external denture form is one of the outstanding milestones in prosthodontics.

In 1886, J. W. White[16] described a concept of denture esthetics he called "correspondence and harmony." He contended that a relationship existed between the temperament of the patient and the form and arrangement of the upper incisor teeth. White also projected the thought that, in the over-all composition, modifications should be made in accordance with the patient's age and sex.

Coincidentally W. R. Hall, in *American System of Dentistry,*[17] published in 1887, describes ovoid, tapering, and square anterior teeth as they seemed to be related to facial form. In this same textbook, the idea is proposed that patients might be classified into four groups—nervous, bilious, sanguine, and lymphatic—and that certain tooth forms, colors, and shapes were related to each type.

In 1914, Williams[18] published the results of his research in relating anterior tooth form to facial outline. His conclusions are still reflected in our thinking; however, a valid adverse criticism of William's conclusions might be that consideration of outline form, alone, in a single plane, is subject to the artistic limitations of abstract art. It would seem that, in addition to outline, depth of form and placement of each tooth as an integral part of a unified composition should be given equal emphasis. This concept has been well worked out by Frush and Fisher[19] in their recent excellent work.

And so, for the past 75 years, at least, prosthodontists have been trying to classify denture patients with a view to connecting each class with a certain tooth form and arrangement. First, we had "nervous, bilious, sanguine, and lymphatic" as classes; then we had the "square, tapering, and ovoid" classes; and now we have "sex, personality, and age" classifications.[19]

New ideas usually have an old background. When explored, they are usually found to have been given emphasis before. The encouraging thing, however, is that each time the picture gets better.

It is a human trait to be impatient with tedious processes. We are always looking for a foolproof system or, even better, a machine which will think and work for us. Perhaps that is why the old masters never showed a subject in their paintings with teeth. Maybe they could not find a good classification.

THE WAY THE DENTURES FIT EACH OTHER

It does not matter that the dentures are meticulously fitted to the ridges and palate of the patient and it does not matter that the external forms are in harmony with the internal form of the oral cavity if, when the patient bumps the lower denture against the upper one, both are displaced.

The way that the dentures fit each other is a dynamic relationship, and it is divisible into four parts. They are (1) the vertical relationship which is based upon a distance that each denture should be from the other one when the mandible is at rest, (2) the angle of the occluding plane as referred to a plane which is parallel with the ridge crests as viewed from the side, (3) the centric relationship in the frontal and sagittal aspects, and (4) the forms of the occluding surfaces.

A disastrous but frequent error is the establishment of a vertical dimension which provides an insufficient interocclusal distance between the dentures when the mandible is in rest position. A wave of enthusiasm in the 1920's guided many dentists to employ "bite-opening" methods in prosthodontics. This was done in the rehabilitation of mouths having natural teeth present and in mouths which were edentulous. A consequence was much tooth and alveolar ridge destruction. Tench[20] and Schuyler[21] warned the profession that these bite-opening techniques would destroy alveolar support by shortening or eliminating the interocclusal distance between the teeth.

There are several reasons why this error is still common. These include (1) a desire to make the lower third of the patient's face more youthful appearing by stretching the facial muscles, and (2) an effort to eliminate tripping of upper incisors over lower incisors when the posterior chewing units are flat in form and arranged upon a flat plane.

Good appearance, for most patients, requires a vertical incisal overlap. Tripping action must be neutralized by an increase of cusp height of the posterior teeth or by steepening the curve of the posterior occlusal plane (compensating curve).

Many methods of measuring the vertical dimension have been suggested. Some are based, quite empirically, on an average relationship of facial distances. Some are based upon facial appearance. Inasmuch as the mandibular rest position and the occluding position are functional or postural positions, it would seem proper to determine these positions with this fact in mind. Several millimeters of space must exist between rest and occluding positions. The rest position can be found clinically. Therefore, a practical method which will provide an interocclusal distance is obvious: Find and record the rest position, then subtract 3 to 5 mm. to find the occluding level.

Niswonger[22] and Gillis[23] reported clinical evidence that the rest position was apparently constant in each individual, that it was not dependent upon the presence of natural teeth, and that it was a postural position determined by muscle function. Removal or wear of the natural teeth did not change it.

Thompson[24] substantiated these observations by study of a series of cephalometric tracings from roentgenograms made of patients' heads before removal of their natural teeth, after removal of these teeth, after placement of dentures, and then several months later. Thompson concluded at that time that the rest position was constant, and that when dentures which did not provide a proper free-way space (interocclusal distance) were placed, the resultant trauma caused resorption of the ridge support until this space was produced.

It was upsetting to see the results of Atwood's[25] research and the findings of Tallgren.[26] Both of these investigators failed to substantiate Thompson's results. Presently, we are wrestling with the dilemma presented by these conflicting conclusions. The subject is extremely important and deserves much further study.

Many years ago a very good friend of our family, Bishop Anderson of the Episcopal Diocese of Chicago, told my mother not to worry too much about some disturbing defections on the part of her children. Said he, "Eventually, they'll come back to their early training, that is, if they have an early training to come back to." So, when I attempt to provide an adequate interocclusal distance, I go back to an idea taught me by my teacher, James Prothero, many years ago. Dr. Prothero used to say to us, "Build the dentures so that they don't come together except when the patient chews or swallows." How could it be stated more simply?

I also find a phonetic test helpful. With the wax trial dentures in place, the patient is requested to say, "sixty-six sailors sailed the Mississippi in sixteen sixty-six, E-E-E," several times (each time a bit more rapidly). If the posterior teeth of the maxillary and mandibular dentures touch each other during this time, an insufficient interocclusal distance has been provided. This is especially certain if,

when viewing the mounted casts on the articulator from the side, the crests of the residual ridges are not parallel or nearly so.

CENTRIC RELATION AND OCCLUSION

In 1930, The National Society of Denture Prosthetists (The Academy of Denture Prosthetics)[27] reported their considered definition of centric relation: "The mandible is in centric relation when the heads of the condyles are in their most retruded position from which the jaw can make lateral movements."

Centric occlusion was not defined or discussed in this report. Centric relation may exist at any degree of vertical opening of the mouth. It is axiomatic that centric relation and centric occlusion must be in harmony. Thus, the centric occlusion position exists when the mandible is in centric relation at a definite vertical opening.

If vertical dimension, once established, is not changed during fabrication of the dentures, centric occlusion may be recorded and integrated into the dentures by the use of a simple hinge-type articulator without using a face-bow. By such a simple method, however, eccentric mandibular positions cannot be recorded.

Since 1840, when Evans patented an articulator which made some provision for lateral and protrusive gliding movements, a great many variations of this idea have been, and continue to be, brought out.

The necessity for recording and attempting to duplicate gliding movements on the articulator has been challenged by several investigators on the grounds that these movements are not masticating movements, but are free movements characteristic of patients who indulge in bruxism. This conflict of opinion is still not resolved.

One of the reasons for using a face-bow is that, within a short range, the vertical measurement may be changed on the articulator without disturbing the accuracy of the centric relation registration. If the change in the vertical dimension must be great, however, it is wise to make new centric relation records unless a fully adjustable articulator, such as the Gnathograph, is employed, with the casts mounted to an accurate hinge axis determination.

McCollum[28] and his associates demonstrated the presence of a constant mandibular hinge axis. Most of their work was done with patients having natural teeth. They employed a jaw writing device which was firmly cemented to the teeth of each jaw. Similar experiments would be difficult with edentulous patients because of inability to fix the occlusion rims firmly to the jaws. The problem would be like that of attempting to use a sextant on a rocking rowboat.

It would seem that, inasmuch as complete dentures rest upon very changeable bases, a meticulous development of cuspal relationships on an articulator might be supplanted by use of cuspal patterns which provide a range of freedom in their occlusal relationships.[29] This could compensate, at least in part, for the malocclusions which come about as a result of denture settling. It is with this thought in mind, that the cuspless or flat forms of posterior artificial teeth were designed and recommended by many prosthodontists. There are disadvantages in the use of flat forms, just as there are in the use of high cusp forms. There is a place for each, depending upon the problems in each patient, but to date no definite rules along this line have been developed. So, this problem, like many others in prosthodontics, merits further study.

With regard to the use of the arrow point or "Gothic arch" tracing device to locate centric relation, I should like to quote further from the 1930 report of the Academy of Denture Prosthetics[27]: "The use of the needle point tracing device for the purpose of determining and checking centric jaw relation is recommended as being both scientific and practical. The Society recognizes no other means of verifying centric jaw relation."

This dictum has stood the test of time fairly well, but it still is not in common use by the dental profession. Like many other devices, it is not foolproof. When used in connection with a central bearing point, the apparatus depresses the tongue because of its bulk. Also, it is nearly impossible to place the bearing point in such a manner that occluding pressures will be equally distributed, particularly for making records of eccentric positions. Duplication of the bearing surfaces of the occlusion rims and the bearing surfaces of the subsequent finished dentures is also difficult. With all of its shortcomings, however, I find great use for this device. One, the Coble Balancer, is especially useful because of the ease with which it is adapted to either baseplate occlusion rims or finished dentures.

BALANCED OCCLUSIONS

Balanced occlusions imply equalized pressures upon all parts of the dentures when they are brought together in chewing or swallowing.

The masticating stroke, as viewed from the front, is semieliptical in form. Each "chew" is completed with the mandibular condyles in a functional postion directed by muscles. At this time, there must be no conflict between the way the teeth fit each other and the way that the muscles wish them to fit each other. This terminal position in the chewing cycle is "centric occlusion." As it is approached, in the chewing cycle, by either a lateral or a protrusive pathway, there must be no tripping interferences. Patients differ greatly in their chewing patterns. Some, who might be called "choppers," chew with a straight, up and down movement, without lateral movement; others, who might be called "grinders," chew with a flattened stroke, with much lateral movement. Each of these classes of patients requires different treatment.

In addition to freedom of action during mastication, other tripping interferences between the dentures, produced by nervous habits such as bruxism, must be dealt with. The pathways of bruxism are different from those of the chewing cycle. This is one of the reasons why the technique of milling completed dentures against one another on an articulator is wrong. By this method the vertical relationship is reduced and errors caused in all other relationships.

CORRECTING PROCESSING ERRORS

With our present-day materials and laboratory procedures, the correction of processing errors is a very important step in denture construction. An effective method is to remount the completed dentures on the articulator in centric relation using the face-bow, then to adjust the articulator to accommodate the lateral and protrusive positions. This is done with interocclusal records.

It has been suggested that the casts and dentures be removed intact from the flasks and restored to their original mountings on the articulator by keying the casts to these mountings. This method brings with it the probable errors which result from the difference in fit of the occlusion rims and the finished dentures.

POSTOPERATIVE CARE

Just as complete denture service does not begin with actual denture construction (careful examination and consultation must precede denture construction), complete denture service does not end with delivery of the appliances. Inevitable changes in the tissues which support the unyielding prostheses and in the temporomandibular joints will change the relationship of the dentures to each other. It is important that the patient understand that these corrections are not due to errors carelessly made by the dentist. The patient must be convinced that subsequent treatment will be necessary and that semiannual examination is essential to the perpetuation of good appearance, comfort, efficiency, and health of the mouth tissues. It is encouraging to find that there is an ever increasing number of patients who can be made to realize this fact. Patients requiring complete denture service are dental cripples. As such, they deserve our best efforts and understanding.

There are many facets of denture service which need further study.

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DENTOGENICS: ITS PRACTICAL APPLICATION

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DENTOGENICS IS THE ART, practice, and technique of creating the illusion of natural teeth in artificial dentures and is based on the elementary factors suggested by the sex, personality, and age of the patient.

The dentogenic restoration is designed to enhance the naturalness of appearance in the individual for whom it is made by its complementary contribution to the beauty, charm, character, or dignity observed in a fully expressive smile or in earnest conversation. The dentogenic concept is an adventure in the realm of cosmetic art.

Auguste Rodin,[1] the famous French sculptor, made this observation: "Art is contemplation. It is the joy of the intellect which sees clearly into the Universe and which recreates it with conscientious vision."

This is the challenge presented in prosthetic dentistry, affording the opportunity for every prosthodontist to grow in the knowledge of Nature's subtleties in color, form, and movement that he may fearlessly recreate with conscientious vision. Thereby he can establish himself as an artist indispensable to the psychologic as well as to the physiologic welfare of mankind.

THREE EDUCATIONAL PHASES

The practical application of the dentogenic concept involves three separate educational phases. The first is the education of the dentist. Axiomatically, the dentist cannot achieve an accomplishment he does not understand any more than the student artist can be expected to produce a portrait comparable to that executed by a master painter. The second is the education of the dental laboratory technician. To many dentists, the laboratory technician is a very valuable assistant; together they form a working team. The third is the education of the patient. In the final analysis, the patient must be satisfied; but without an understanding of the esthetic asset to himself, the patient cannot be expected to desire or even to be willing to submit to the innovations of dentogenics.

EDUCATION OF THE DENTIST

The preceding articles on dentogenics[2,3,4,5,6] have been presented in such detail as to provide the interested and conscientious student with an adequate text. As in all other arts, however, continued practice is essential for increased skill and satisfaction.

This is the last of a series of six articles on dentogenics in the JOURNAL (Refs. 2, 3, 4, 5, and 6).

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The great Polish pianist, Paderewski, is said to have remarked, "If I should miss practicing for one day, I could notice it. If I should miss for two days, my manager could notice it, and if I should miss for three days, the whole world could notice it." He was aware of the constant necessity of association with his music and his instruments in order to maintain his standard of perfection.

The sculptor refers constantly to his model when recreating Nature. The landscape artist takes his camera, palette, paint, and brushes out into the country. Only in such an environment and by continually comparing his canvas to what he is attempting to interpret does he expect his finished handiwork to reflect reality.

So, too, the dentist who desires to excel in his work as a prosthodontist must strive to become exceedingly familiar with the detail of natural dentitions, particularly from the esthetic point of view. He must become so familiar with the dentogenic principles[2,3,4,5,6] that he may be able to apply them for the benefit of the

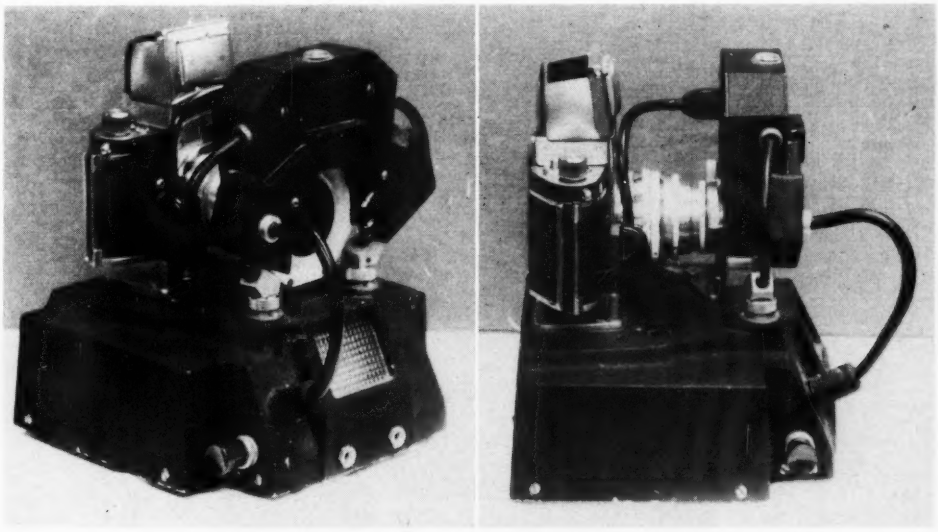


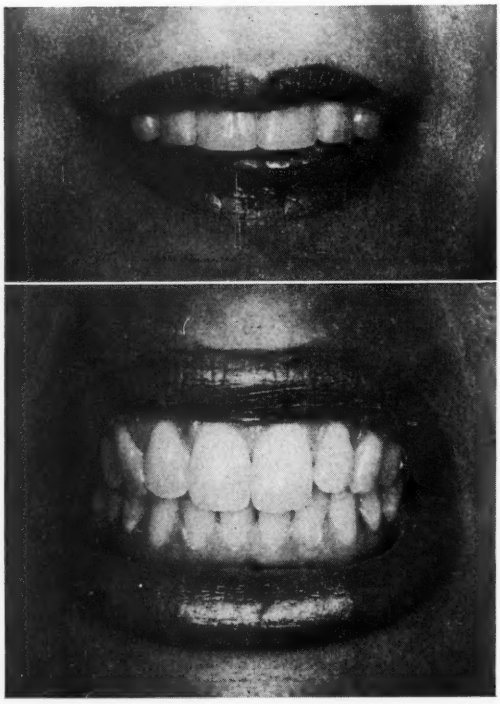
Fig. 1.—The camera used by the authors.

patient whenever possible. It is important to adhere to the routine of photographing the mouth of every patient who sits in the dentist's chair whether the teeth be artificial or natural. This procedure provides abundant study material. There are a number of cameras specially equipped for such work (Fig. 1). If possible, the pictures should be in natural color, since these are so much more revealing than are monotone pictures. These photographs should show the patient's face or head from the front and from each side. They should include close-ups of the mouth with the previous dentures in position or with whatever natural teeth may be present. Pictures of this type are invaluable as pre-extraction records and should be made before any work is begun.

We have asked patients to bring in pictures showing the natural teeth, only to be presented with two or three black and white snapshots taken on a picnic twenty years before, which were designed to show the sweetheart of the moment. We have had to concentrate on these, straining our eyes through a high-powered magnifying glass to catch a glimpse of the central incisors. What a wonderful aid will be available to dentists when each patient is presented with a close-up picture of his natural teeth in color, with the admonition to put it in safekeeping for the day it may be needed.

By making two pictures of the teeth at close range and retaining one for the office records, a most valuable reference library can be built. These pictures constitute a continuing source of fresh material to use in conjunction with the dynesthetic

A.



B.

Fig. 2.—A comparison of artificial and natural teeth. *A*, An artificial-looking restoration. *B*, Natural teeth.

text. In addition, the dentist may study freehand drawing with a local artist. Using pictures as models, the dentist may sharpen his sense of visual perception. In this manner, he will become familiar with the limitless variety of subtle nuances which Nature employs in her artistic designs.

A comparison of the photographs of natural dentitions to most artificial dentures will reveal striking conflicts (Fig. 2). It should be possible to analyze the real and the artificial, to make comparisons and, from what is learned, to avoid the pitfalls often found in the conventional denture tooth arrangement.

The task of arranging the visible teeth to reflect the personality of the patient, according to the dentogenic concept, is definitely the responsibility of the dentist. The utmost familiarity with these teachings is necessary, therefore, in order that the end result may be satisfying to him as well as to the patient. If the dentist is not familiar with the dynesthetic procedure, he can hardly be expected to approach the problem with confidence. To each tooth in the visible arch falls a peculiar dynesthetic responsibility; and until one has practiced and persevered to the point of understanding the technique, the full pleasure of accomplishment cannot be realized.

There is a most rewarding opportunity for the prosthodontist in this work as he sits quietly at the patient's side and places one tooth after the other in the wax rim, while requesting the patient to smile or speak seriously in order that the desired effect may be accomplished in the reproduction. This experience gives the prosthodontist the opportunity to impress the patient with his particular skill and artistry. The dentist, at the same time, is privileged to establish a state of rapport with his patient. In this, the patient may be guided and directed to understand the esthetic objectives of the dentist, to accept his efforts, and to arrive at a harmonious conclusion. It is indeed an opportunity to establish professional prestige.

Satisfaction, however, is not always easily achieved. No artist paints a masterpiece every time he paints a picture. Likewise, it is not possible that every arrangement made by the dentist will be equally gratifying to him. As with the pianist, Paderewski, so with the prosthodontist; persistence and practice are necessary in order to gain and maintain the acme of inspired accomplishment.

EDUCATION OF THE LABORATORY TECHNICIAN

Some dentists must delegate to assistants as much of their work as possible. The dental laboratory technician is such an assistant. He may (when supplied with the proper prescription) embody in the denture composition with relative success the dynesthetic subtleties and refinements necessary to satisfy the dentogenic requirements of the patient. Verifications by the dentist, by trial with the patient, are necessary before the denture is completed.

The scope of the laboratory technician's assistance has been covered in a previous article.[6] However, unaided by the dentist, "the laboratory technician cannot produce a dentogenic restoration, because he does not come in direct contact with the patient; nor is he professionally trained to meet the challenge posed by the complexities of patient management."[6]

Many of the dentures observed today sadly reveal that the tooth arrangement has been executed by someone totally unacquainted with the patient, by someone even uninformed of such basic facts as the patient's sex, age, and personality.

Armin Landeck,[7] a contemporary artist, says, "I can paint the average more or less perfect egg from memory, and at times enjoy the illusion that I have invented it, but I wouldn't care to paint a wrinkled egg without a model." Certainly the arrangement of teeth for any patient must be considered a more important and critical task than the casual painting of "a smooth egg"! To prepare a denture

composition without seeing and studying the patient could, and frequently does, result not only in incongruity but in distortion of the patient's personality and destruction of his morale. When he is qualified, however, the dental laboratory technician may, upon advice from the dentist, apply the dynesthetic procedures which are an essential part of his technique. This advice may be transmitted to the laboratory technician by means of a specific prescription form. This form has been created for the purpose of conveying pertinent dentogenic and dynesthetic information to the laboratory technician.

Since the patient is known to the technician only through the dentist, the ultimate success of the denture composition is in the dentist's hands. *He* must be the artist. Only in the proportion that he assumes this responsibility and strives understandingly can he realize the *summum bonum* of his profession—the rewarding satisfaction of knowing that his artistry has succeeded in enriching another's personality and life.

EDUCATION OF THE PATIENT

Alexander Pope,[8] in his famous *An Essay on Man,* gives us this familiar quotation, "Tis education forms the common mind; just as the twig is bent, the tree's inclined." In the education of the patient, it becomes requisite to initiate this bending of the twig as soon as possible. After the many years of drought in the field of esthetic effort and information, all the resources at our command are needed to enlighten the misinformed so he will accept the meaningful but sometimes unanticipated changes which are indispensable in the application of the dentogenic concept.

First, we must acquaint our patients with Nature. Obviously nothing else can succeed here as well as do pictures. The dentist may employ a loose-leaf notebook with plastic inserts under which may be placed pictures cut from current magazines (Fig. 3). These pictures can be of well-known people who display excellent natural teeth. The television and motion picture stars create immediate interest because of their familiarity. These will supply abundant material for this purpose.

Some of these pictures may illustrate the effects of well-intentioned but unfortunate cosmetic efforts in restorative dentistry. Patients learn very quickly to tell the natural from the artificial and present the prosthodontist with a stimulating challenge.

The pictures should show natural teeth in the mouth in serious speech and during expressive smiling. Pictures should be selected to illustrate the dynesthetic phase of the dentogenic concept, such as the variable long axes of the anterior teeth, active or passive positions of central incisors, the "soft" and "hard" placement of the lateral incisors, and the canines in the desirable and the less pleasing inclinations. The alertness of the dentist or of his well-informed staff will result in a continual accumulation of some pictures and discarding of others as further understanding develops keener vision and the "smooth egg" ceases to satisfy. Ultimately, the patient education manual becomes an indispensable aid.

This book will assist in the re-establishment of Nature's design in the mind of the patient and sharpen his recognition of the artificial. The preparation of the

prosthodontist to accept the responsibility which is bound to follow such patient enlightment is obligatory.

A frequent challenge to the artistically awakened prosthodontist is the patient who is aware of the cosmetic shortcomings of dentures which have been retained years longer than they should have been, but who "does not want to look different" with new dentures.

One of the greatest errors in dentistry in the last 40 years has been that of permitting the patient to wear his dentures for too long a period of time. On this point, much education is necessary. Many patients come into our offices and state that they have worn their dentures for 15 or 20 years. Obviously in these circumstances, they have acquired a tolerance of tooth positions in the mouth that are totally different from the positions of the natural teeth. In many instances, resorption has occurred and the dentures have disappeared from sight. Consequently, when an attempt is made to return the teeth to the approximate position of the natural teeth, the effort is met with resistance. The vast majority of dentures worn today are a detracting factor to the wearer cosmetically, yet to effect the acceptance of a change

Fig. 3.—A loose-leaf notebook is employed to demonstrate the arrangement of good-looking natural teeth.

in appearance often requires patience, persistence, and persuasion. It has been said that people notice *change* before they notice *improvement*, and this must be anticipated in the attempt to effect a dentogenic restoration. Many factors run through the mind of the patient when he observes himself wearing a new arrangement of teeth. These must be anticipated, and encouragement must be given to him by again referring to the pictures in the patient educational manual.

The unfortunate adjustment of patients to the gradual change in the denture position in the mouth which takes place is truly amazing. Many patients will go 5, 10, or 15 years with no apparent awareness of the detriment to their appearance caused by the resorption of the ridges and consequent settling of the dentures.

Naturally, when the attempt has been made to rectify the situation and to undo the results of several years of neglect, the patient may be astonished and deeply concerned upon looking into a mirror. Then it is that all the knowledge, skill, and information at the dentist's command must be brought into play. If he has not participated personally in the arrangement of the teeth, it will be very difficult for him to inspire confidence and allay doubt.

The dentist must be thoroughly familiar with all the dentogenic and dynesthetic factors in order make certain that the highest degree of beauty, charm, dignity, and character has been embodied in the composition which he has created. Then it is possible to point to its logic and to receive ready acceptance.

The matrix or denture base is an exceedingly important feature of a denture. In most cases, certain portions of the matrix should be visible. In the past, the usual effort was to avoid any display of the denture base, even when the patient indulged in a fully expressive smile. In order to meet a possible objection by the patient to the showing of the interdental papillae or gingival matrix, it is expedient to refer again to the collection of magazine pictures of smiling people. These will reveal that those who possess natural teeth do display some portions of the gums when smiling.

By so doing we can obviate having to deal with that most common retort, "Doctor, I never showed my gums." Of course this statement is usually not factual; it is a defensive attempt to avoid being the unhappy recipient of a denture whose matrix bears little resemblance to natural gum tissues.

SUMMARY

The dentogenic concept is an esthetic philosophy. Its purpose is to present knowledge whereby the prosthodontist may replace the lost dentition in such a manner as to effect an appearance which is complimentary to the sex, personality, and age of the patient.

Other interests have seemingly occupied the attention of the profession, to the unfortunate exclusion of the esthetic or cosmetic phase. The result of this disinterest has been an impersonal, characterless, or mechanical arrangement of teeth.

The dentogenic concept has been explained and demonstrated for the benefit of the dentist and the dental laboratory technician. The technician has been enlightened so that he can lend a helping hand to the dentist when needed.

Both physical aids and knowledge have been placed in the hands of the dentist so that he may be able to guide the patient to "look with the eye, and see with the mind," and thus believe in his dentist's ability and understand his reasoning. Only in this manner can there be a welcome acceptance of the inspired efforts of the dentist, and the entire profession can be led to nobler heights in its service to mankind.

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THE MAXILLOMANDIBULAR RELATIONSHIP OF CENTRIC RELATION

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IN A MOMENT of thoughtlessness in 1951, I allowed myself to become involved in writing an article which was entitled, "A Review of Some of the Problems Associated With Centric Relation."[1] The thoughts expressed in that article were not original as the title indicated, but were in review.

In the past 7 years, as I have struggled with, thought about, and studied this relationship, I have become increasingly thankful that the phrase "some of the problems" was used. When one considers the number of articles on this subject, the various definitions given, and the number of methods suggested for recording this position, the term "problems" appears more appropriate than I had imagined. In 1956, Sicher[2] wrote, "Where, then, do we stand today in the controversy over the jaw relations in centric position? I think it would be best to reserve judgment and to consider 'centric' or 'ideal' or 'harmonious' mandibular position as the definition of a problem rather than of a solution."

The importance of recording this maxillomandibular relationship accurately in prosthetic procedures needs no emphasis. Many authors state that it is the most important jaw relation we seek to record in our attempt to rehabilitate the edentulous patient. There are those who believe that many different techniques for making complete dentures will give acceptable results, provided they are fabricated at the correct centric relation, with a comfortable interarch distance of occlusion, and with the teeth in the proper position.

In a short discussion of a subject which has received the attention of so many excellent men, there appears but one path to follow. It is to state your own view of the problem, and if you are wrong, it is beneficial to become aware of it. If you are correct, you add a little more verification to those who have stated the same thing previously.

It has been stated that in order to record centric relation it is necessary to be able to define it. This seems logical; however, long experience in teaching leads me to wonder if a knowledge of a definition alone is enough. Does not the dentist need a mental image or concept of that which he seeks to accomplish?

There appears to be a current tendency to influence the wording of a definition according to the specific phase of study engaged in by the individual. Hence, the physiologist, the anatomist, the prosthodontist, etc., express their definitions differently. This is probably as it has to be; however, it is confusing to some.

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I am not here to defend the so-called prosthetic definition, even though I believe it to be a descriptive one. Neither do I wish to criticize some of the recent definitions which have been suggested. I have no desire or ability to advance a new definition, even though we are having an open season in that endeavor. Rather, I would like to put forth a plea that we strive for some common clinical concept of this relationship, its relation to our plan of occlusion, its influence upon the potential success of restoration, its influence upon the supporting structures, the stability of our dentures, their comfort, etc.

If I may take the liberty to cite two comparatively recent definitions, they are as follows: "*Centric relation* is the position of the mandible as determined by the neuromuscular reflex first learned for controlling the mandibular position when the primary teeth were in occlusion."[3] Another is, "Centric position of the mandible is best defined as the ideal, totally harmonious, or balanced occlusal position, in which not only all the teeth are in proper contact, but also the joints and their muscles are in equilibrium."[4] I have no objections to these definitions; they undoubtedly are excellent physiologic explanations. I do wonder, however, if these statements place the general practitioner in a better position to judge the accuracy of a record of centric relation made by a patient who has just lost the 12 anterior teeth after having been edentulous posteriorly for the previous 6 years.

To pass upon the accuracy of any record is the responsibility of each individual dentist, regardless of the technical method used in securing this record. If this be true, then his judgment in meeting this responsibility must be influenced by his concepts of the jaw relation he seeks to record.

To explain this clinical concept, which I sincerely believe is necessary for the dentist to possess, necessitates dividing it into four parts: (1) a concept of the position, the anatomic picture; (2) a concept of the use he will make of this record; (3) a concept of the possible causes of errors in recording this relationship; (4) a concept of centric occlusion.

CONCEPT OF THE POSITION

I risk the danger of oversimplifying a complex mechanism, in the hope of developing a clinical picture as well as avoiding repetition of information known to all of you.

The mandible, articulated to the skull as it is, is limited in its range of possible vertical, anterior lateral, and anterior movements by anatomic entities.

If the mandible can be made to carry out the extremes of possible horizontal movements for a given degree of vertical opening, the resultant graph would show the envelope of possible movement, which is sometimes called the outline of the movement area. This well-known fact is not a plea for the needle-point tracing or the House rhomboid pattern developed by a functional registration, nor does it refer to a functional movement pattern. It does prove to me, at least, that a posterior terminal position does exist. It is the point of origin of anterior movement. Whether the patient uses this point frequently or not, it must be accommodated in our plan of occlusion. Therefore, I like to think of centric relation as this reference point.

CONCEPT OF THE PURPOSE OF THE RECORD

Even though it is elemental, the concept of the purpose of the centric relation record should impress the dentist with the importance of this registration to the success of the endeavor.

In the development of a complete denture restoration for either one or both arches, it is the responsibility of the dentist to establish centric occlusion. Centric occlusion, according to the *Glossary of Prosthodontic Terms*,[5] is: "The relation of opposing occlusal surfaces which provides the maximum planned contact and/or intercuspation." As stated in the definition, it is a "planned" contact—literally man-made, and it is developed upon the record made by the patient and accepted by the dentist. It seems reasonable to assume that this position of occlusion must accommodate the most posterior position from which it is possible for anterior movement of the mandible to originate.

Balancing contacts to accommodate eccentric positions anterior to centric occlusion can be provided for in the occlusion plan. No such opportunity exists, however, for providing a similar accommodating balance of occlusion posterior to the centric occlusion which has been established. Therefore, the purpose or use of this record is to provide a reference point for the development of the plan of occlusion. Engineering-wise, the centric relation record would have to be made at the point from which only anterior movement is possible.

One other important use of this posterior terminal point or position should be recognized. It is the reference point used for the determination of occlusal interferences in centric occlusion. What are the periodontist, the restorative dentist, the prosthodontist, and even some orthodontists doing when they tease the mandible of the patient back to its posterior terminal position? Are they not using this reference position to determine if this position is provided for by equilibrated contact?

CONCEPT OF THE CAUSES OF ERRORS IN RECORDING CENTRIC RELATION

A brief discussion does not permit my becoming involved in consideration of *methods of recording* centric relation. From a prosthetic viewpoint, the dentist's awareness of some of the possible causes of errors should explain the necessity for verifying the relation of the casts on the articulator with the relation of the mandible to the maxillae on the patient. This is accomplished by the only clinical method available, that of rechecking.

Sources of errors can be grouped into two categories: technical and those of patient origin.

Technical causes of errors include poorly adapted registration bases, carelessness in assembling the record on an occluding frame, displacement of the recording bases by the dentist in attempting to force the mandible into its terminal position, excessive closing pressure by the patient in instances of easily displaceable supporting tissue, and the use of a too-resistant recording medium. These and many other technical details can cause an error in the record we seek to obtain from the patient.

Errors of patient origin are those caused by tensions, habits, and moods of the patient, and the influence of the dentist's attitude (if the dentist becomes confused and irritated, what does he think happens to the patient?), irritation caused by the registration bases, or general tenderness of supporting ridges. These and other conditions render the patient equation most difficult at times.

Erroneous registration records can and do occur. These experiences will always be with us. This is a part of the game in rehabilitating the edentulous patient, however, rather than an *excuse* for neglecting to recheck until the accuracy of the terminal position is verified. Is there anyone who cannot recall instances where he has had to remount casts many times before attaining the goal he sought?

Two statements may be made regarding methods of registration in explaining my theme of *concept*: First, while I do not feel that the needle-point tracing is infallible in locating centric relation, I do feel that it aids in developing a concept of the border movements and positions. Second, those who have attempted to locate the hinge axis of the mandible have developed a clear concept of the posterior terminal position of the condyles.

CONCEPT OF CENTRIC OCCLUSION

Centric occlusion and centric relation are so interrelated that the two go hand in hand in any discussion. In fact, this appears to be a confusing thing in our nomenclature. One finds himself saying occlusion when he means relation, and vice versa.

I have stated my concept of centric relation as a posterior terminal point or position of reference, the most posterior point of origin of possible anterior movement. My concept of centric occlusion is not a point, but an area, limited and variable in its anterior extent in different individuals.

Centric occlusion must permit equilibrated accommodations of the reference point (the posterior terminal position), and in a like manner it must accommodate an easy closing position which may be slightly anterior to the posterior terminal position.

The provision for freedom in centric occlusion is not new; reference to "freeing occlusion" has been made many times. Various milling devices have been suggested for this purpose. Stansbery used a rotary grinder which provided 0.016 inch of clearance anteriorly and posteriorly to the centric relation position of the mounted casts. Terrell, with a similar device, could set or control the amount of clearance. The House rotary grinder freed the occlusion either anteriorly or posteriorly, depending upon the setting of the pulley at the time the casts were mounted.

If we analyze these milling devices, it can be seen that when the articulator is locked in the centric relation position for equilibrating centric occlusion, the contacts in centric occlusion are freed because of the rotary movement of one of the casts. The contact *area of freedom* is a plateau or horizontal area because the cast is rotated in the horizontal plane. Such an area of freedom of centric occlusion is difficult, if not impossible, to develop on an axis articulator. In this type of articulator, any movement of the cast involves moving the maxillary member of the

articulator. This maxillary member is guided by the incisal table and condylar guidances. If any one or all of these guiding planes are inclines, then the grind-in results in a point contact in the centric occlusion rather than an area of contact.

To prevent misunderstanding, this is no plea for zero-cusped teeth. Monoplane teeth face the same requirements as any other pattern of occlusion in that the centric occlusion they establish must accommodate the same reference point. They are not an easy way out for failure to record the correct centric relation.

These concepts are not new; I bring them back in the hope that out of it all will come helpful suggestions in this important step of prosthetic procedures.

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A CLINICAL STUDY OF THE CONDYLE PATH

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THE PATH OF THE CONDYLE has been the subject of intensive investigation by many prosthodontists. Balkwill[1] first described the movements of the jaw in 1866. Since then Gysi,[2] Hanau,[3] and McCollum[4] have reported their studies of condylar movements. This article will report a study of the translation of the condyle.

TRANSLATION, ROTATION, AND THE BENNETT MOVEMENT

Translation is a basic, component movement of the opening functional movement as well as of the glide or afunctional movement (Fig. 1). Another component movement is rotation of the condyle. Rotation occurs between the condyle and the inferior surface of the interarticular disk. The center of rotation of the mandible is located within the condyle. In function, rotation occurs in combination with translation. The patient can be taught, however, to eliminate the translatory movement and achieve pure rotation. Then, the center of rotation of the condyle can be located at the point closest to the condyle on the adjacent skin.

The meniscus is held tightly against the condyle by the capsular ligament, which permits only a limited range of movement between the condyle and the disk. The disk and condyle combined, however, are permitted a wider latitude of motion between themselves and the articular surface. Nerves stimulate the muscles, the muscles activate movement of the condyle, and the muscles, ligaments, and bony framework limit the amount of movement of the condyle. The movement that the disk and condyle make in combination is termed translation. During a forward protrusion of the mandible, both condyles move by translating along the articular surface. During a right or left lateral excursion, one condyle remains within the general confines of the glenoid fossa as the opposing condyle moves along the eminence. During functional movements, both condyles rotate on the undersurface of the disk as the disk and condyle translate along the eminence in unison.

The Bennett movement is a component of the glide or excursive movement and occurs during such mandibular movements as grinding of the teeth. The Bennett movement is the lateral shift, bodily, of the condyle which remains within the general confines of the fossa. The amount and type of shift, as recorded by movement of the center of rotation, have been tabulated in a previous article.[5]

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In some patients the condyle assumes a position which is out of the normal range of excursive movement of the condyle. Laxity of the muscles and ligaments during phyisologic rest or muscle fatigue allows the condyle and disk to drop from their superior position in the glenoid fossa. Patients with loosely held condyles, as a result perhaps of torn ligaments, are more likely to develop this sagging of the condyle out of position. This condition may be designated as the condylar position during physiologic rest of the mandible.

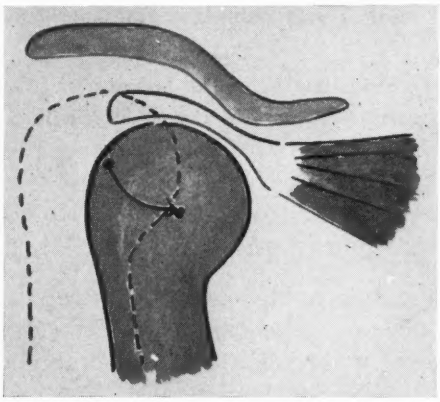

Fig. 1.—The disk and condyle move in unison along the articular surface during translation. The external pterygoid muscle is attached to the disk and to the anterior portion of the condyle.

The movement of the centers of rotation of both condyles during a lateral excursion and a forward protrusive movement, in the frontal and sagittal planes, respectively, is seen in Figs. 2 and 3. These diagrammatic illustrations differentiate between lateral and forward movements and show the range of movement that the centers of rotation can achieve in each case. In centric relation the condyles are within the confines of the glenoid fossae. During an extreme lateral excursion the translating condyle moves (Figs. 2, *A* and 3, *A*) to a position at the medial, lower, anterior portion of the eminence. The other condyle remains within the confines of the glenoid fossa, and if there were no Bennett movement it would merely rotate, with no movement bodily. During a forward protrusive excursion both condyles move (Figs. 2, *B* and 3, *B*) from their positions within the fossae to the lower, anterior, but more lateral part of the eminence. The area within the extreme lateral excursive, forward protrusive, and centric relation positions is the range of movement (Figs. 2, *C* and 3, *C*) that the centers of rotation are capable of making.

ESTABLISHING THE REFERENCE PLANE

This study was designed to measure the angle and radius of the condyle path. The method recorded the movement of the centers of rotation of each condyle in the sagittal plane. To record the condyle angle, it was necessary to relate the centers to a third point so that a reference plane could be established. The third point was the infraorbital notch of one of the orbits. Thus, a reference plane known as the

orbital plane was established. The *angle* between the condyle path and the orbital plane was called the condyle path angle; the *curvature* of the condyle path was called the condyle path radius.

RECORDING THE TRANSLATORY MOVEMENT

The Gnathograph (Fig. 4) is an instrument devised by McCollum and the Gnathological Society of California.[4] The exact translatory movements of the

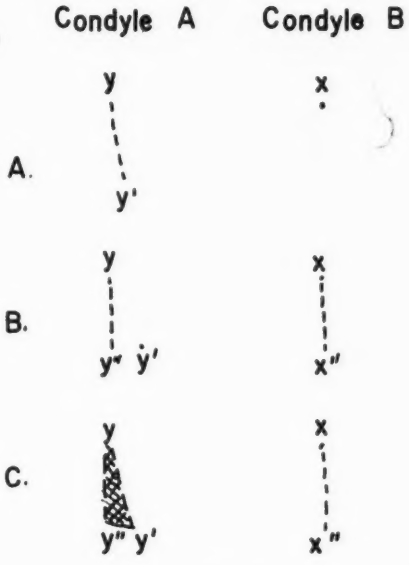

Fig. 2.

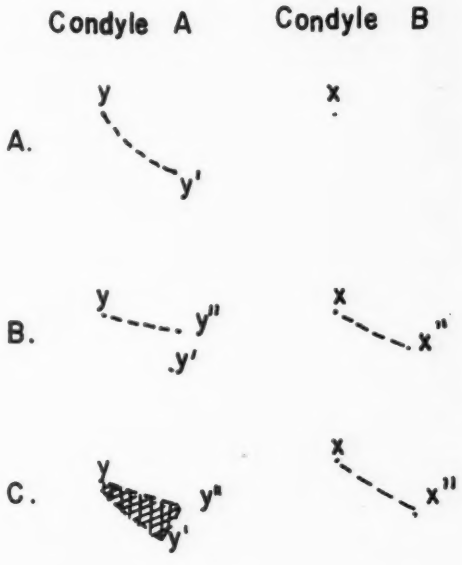

Fig. 3.

Fig. 2.—*A*, The movement of the centers of rotation of the condyles during translation in the horizontal plane; *y* represents the rotational center of condyle A at the start of translation during a lateral excursion and *x* represents the rotational center of condyle B as it is positioned within the confines of the glenoid fossa at the start of an extreme lateral excursion. Condyle B does not have a Bennett movement. Therefore, as condyle A moves from point *y* to point *y'*, condyle B will merely rotate around point *x*.

B, The movement of the centers of rotation of the condyles during a protrusive movement in the horizontal plane. In a protrusive movement, the centers of rotation will move from points *y* and *x* to points *y"* and *x"*. Note that there is a different end position between the straight protrusive end point, *y"*, and the extreme lateral position, *y'*.

C, The range of movement of the centers of rotation of the condyle during excursive movements in the horizontal plane. The range of movement that the center of translating condyle A can achieve is the shaded area enclosed by *y*, *y'*, and *y"*.

Fig 3.—A, The translatory movement of the centers of rotation of the condyle in the sagittal plane; *y* represents the rotational center of condyle A at the start of a lateral excursive translatory movement and *x* represents the rotational center of condyle B as it is positioned within the confines of the glenoid fossa at the start of an extreme lateral excursion. Condyle B does not have a Bennett movement. Therefore, as condyle A moves from point *y* to point *y'*, condyle B will merely rotate about point *x*. The conclusion of the translatory movement is represented by *y'*

B, The protrusive movement of the centers of rotation of the condyles in the sagittal plane. In a protrusive movement, the centers of rotation will move from points *y* and *x* to points *y"* and *x"*. Note that the extreme position of the forward protrusive movement, *y"*, differs from the extreme lateral excursive position, *y'*.

C, The range of movement of the centers of rotation of the condyles during excursive movements in the sagittal plane. The range of movement that the center of translating condyle A can achieve is the shaded area enclosed by *y*, *y'*, and *y"*.

Fig. 4.

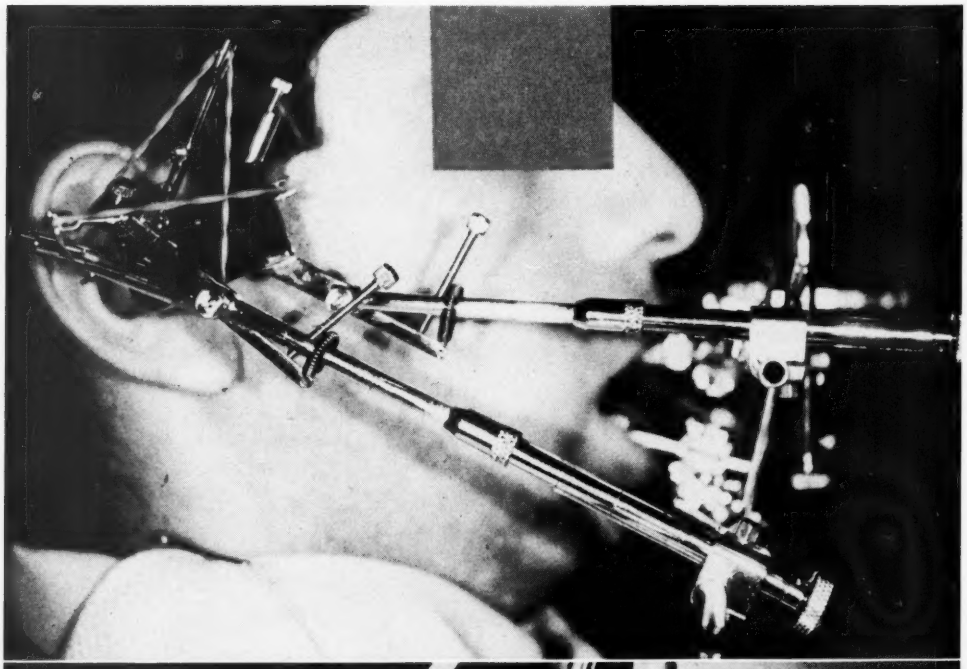

Fig. 5.

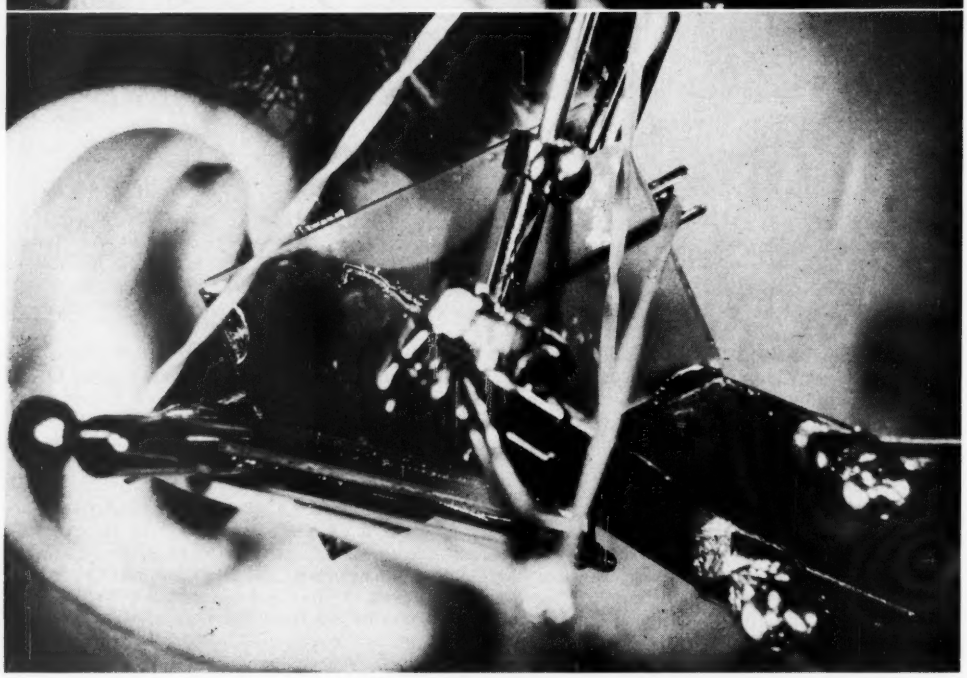

Fig. 4.—The Gnathograph is in position on a patient. The instrument is used to record mandibular movements.

Fig. 5.—The condylar slide illustrates condylar movement in the sagittal plane on the outside of the face near the condyle. This slide is most suitable for the clinical study of the translatory movement.

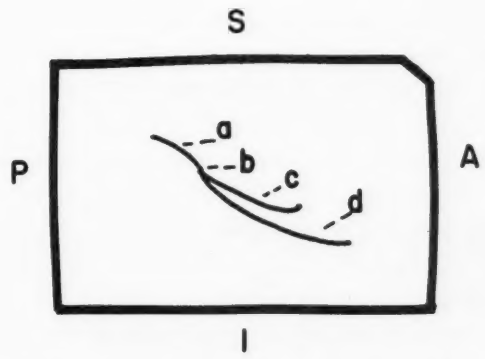

Fig. 6.—A diagram of the sagittal slide on the outside of the skin near the condyle is used to study translatory movement. *P*, The posterior edge of the slide, *A*, the anterior edge, *S*, the superior edge, and *I*, the inferior edge. *a*, The short line which is made by the condyle which remains within the confines of the glenoid fossa, *b*, the centric relation, *c*, the protrusive translatory movement, and *d*, the lateral excursive translatory movement. The angle and radius of the condyle paths are derived from a study of lines *c* and *d*.

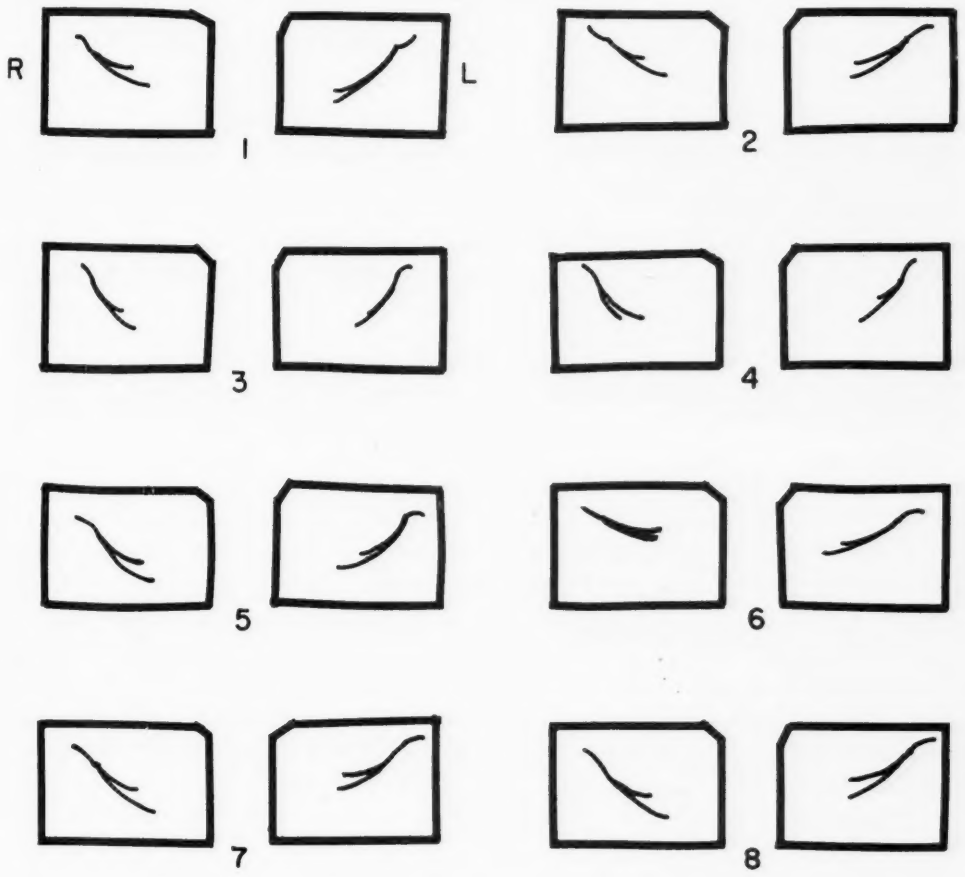

Fig. 7.—Records were traced from the original glass slides of eight patients whose jaw movement registrations were made with the Gnathograph. *R*, The records of the movement of the right condyle. *L*, The records of the movement of the left condyle.

condyle centers can be recorded with this instrument by means of two face-bows which record jaw movements in three dimensions.

The maxillary and mandibular face-bows are fixed separately to the two jaws by means of aluminum trays, called "clutches," which are cemented to the teeth with a zinc oxide and eugenol paste. The clutches are kept from interfering with each other and the opposing teeth by means of a central bearing device. The jaw movements are recorded on waxed glass slides which are attached in three different planes to the face-bows. The arrangement gives a three-dimensional registration of jaw movement.

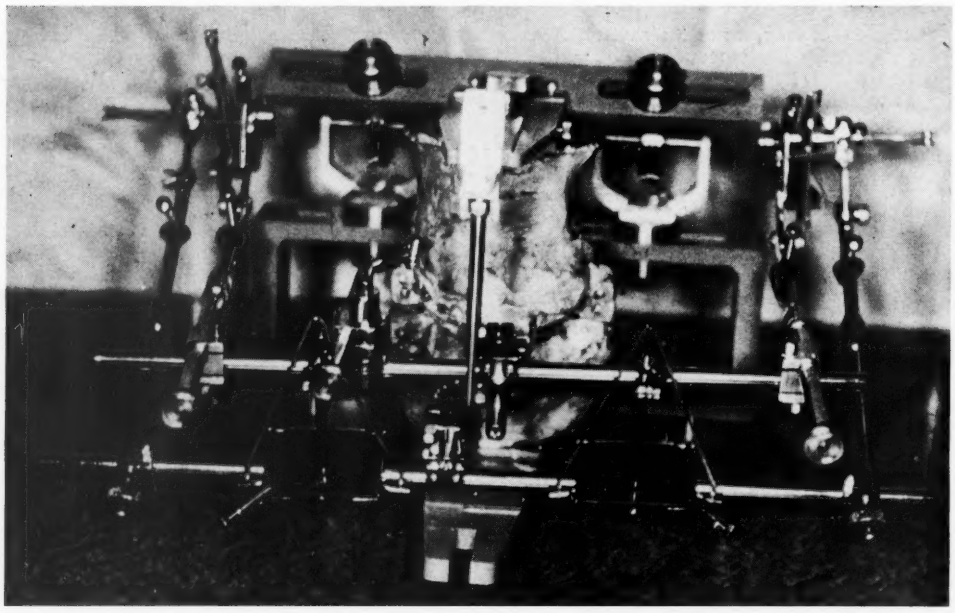

Fig. 8.—The Gnathograph is mounted on the articulator. The Gnathoscope is adjusted to follow the paths that the patient recorded on the glass slides.

Two glass slides are placed diagonally, one on each side of the condylar region, between the frontal and the horizontal plane. These slides clearly illustrate the Bennett movement. Two more glass slides are located in the anterior region, one on either side of the symphysis, and are used to record the movement in the horizontal plane. Typical Gothic arches are traced on these slides. And two more glass slides are located in the sagittal plane in the condylar region and clearly illustrate the movement of the condyles in this plane (Fig. 5). They are of particular interest in this study.

The slides are coated with a thin layer of carnauba wax, and the movements are traced by steel styli which are held against the glass by means of elastic bands. After the recordings are made, by consistent technique, and traced clearly, the wax tracings are etched with hydrofluoric acid. Thus, a permanent record of the patient's jaw movements is obtained on the glass slides.

A diagram of the slide in the sagittal plane is illustrated in Fig. 6. Three lines stem from the point which indicates centric relation. These lines are established when the patient moves the mandible first in a straight protrusive movement, then in an extreme lateral movement, and finally in a lateral excursion in the opposite direction.

Fig. 9.

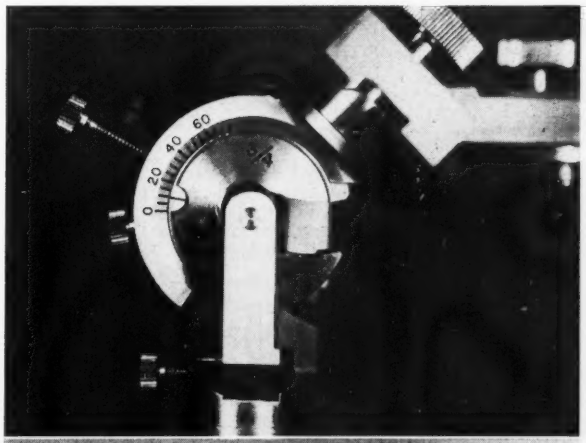

Fig. 10.

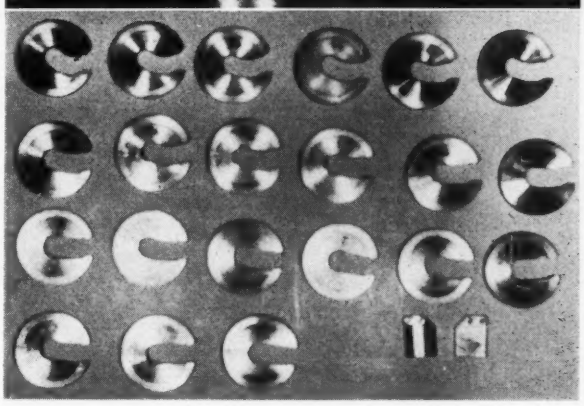

Fig. 9.—A ¾ inch condyle path is inserted in the articulator. The angle has been adjusted to 9 degrees.

Fig. 10.—A set of interchangeable condyle path radii is available. The patient's condyle path tracing is analyzed, and a suitable path is fitted into the articulator to follow the radius of this path.

Eight sets of the condyle slides are illustrated in Fig. 7. They show the variety of angles and radii the condyle paths can make. Shallow angles and radii and steep paths and short radii are intermingled in a wide variety of paths.

The angle and the radius were determined as follows: The patient made a complete set of movements which were recorded with the aid of the Gnathograph. The recordings of the movements were mounted on the Gnathoscope, a fully adaptable articulator (Fig. 8). Then, the articulator was adjusted to follow the paths of the

tracings. The angle of the path can be adjusted easily (Fig. 9), but the radius must be altered by the use of interchangeable paths. A large variety of paths are available with radii from 3/8 of an inch to infinity (Fig. 10). The angle is adjusted and the required path radius inserted; the articulator can then follow the patient's condyle path.

STATISTICAL ANALYSIS

A statistical analysis was made of the variations in the recordings of 36 patients (Table I). The age and sex were noted, along with the angle and radius of the right and left condyles. The findings were examined to see if a pattern could be established.

TABLE I. CHARACTERISTICS OF THE CONDYLE PATH IN 36 PATIENTS

PATIENT	AGE	SEX	CONDYLE PATH ANGLE (DEGREES)		CONDYLE PATH RADIUS (INCHES)	
			LEFT CONDYLE	RIGHT CONDYLE	LEFT CONDYLE	RIGHT CONDYLE
1	23	M	27	31	2	7/16
2	42	M	31	45	3/8	5/8
3	56	F	31	28	7/16	5/8
4	35	M	29	27	1	5/8
5	36	M	40	53	7/8	9/16
6	39	F	38	38	1	3/4
7	45	F	33	32	3/4	1
8	54	M	27	29	3/8	5/8
9	55	M	37	33	3/4	13/16
10	56	M	34	42	2	1 1/8
11	41	M	45	26	1 1/8	1
12	46	F	24	27	7/8	13/16
13	23	F	32	34	11/16	3/4
14	30	M	42	42	3/4	3/4
15	45	F	27	28	9/16	1/2
16	19	M	40	44	3	11/16
17	46	M	23	32	13/16	2 1/2
18	59	M	35	39	7/8	3
19	60	M	44	22	3/4	1/2
20	41	F	37	37	5/8	9/16
21	22	F	39	35	5/8	5/8
22	56	M	41	39	3/4	1
23	56	F	45	45	2	5/8
24	36	F	36	33	3/4	1 1/2
25	40	F	35	33	7/8	1/2
26	55	F	40	43	1/2	5/8
27	26	M	27	28	1/2	1/2
28	49	M	32	36	13/16	1
29	36	M	38	37	1/2	3/8
30	56	M	34	42	2	1 1/8
31	41	F	38	50	7/16	3/4
32	45	M	49	50	1 3/4	1/2
33	54	M	42	48	1	1/2
34	32	M	28	24	3/4	11/16
35	58	M	37	39	1/2	1/2
36	56	M	27	29	3/8	5/8

The condyle path angles ranged from a minimum of 22 to a maximum of 53 degrees. The average condyle path angle for the entire group was 35.64 degrees; the

average for men was 35.82 degrees and for women 35.31 degrees. The average condyle path angle for patients below age 40 was 35.08 degrees, and that for patients over age 40 was 35.7 degrees. The average condyle path radius for both men and women was 7/8 of an inch.

The average condyle path angle of the left condyle was 35.11 degrees, and that of the right condyle was 36.02 degrees. The average condyle path radius of the left condyle was 15/16 of an inch, and that of the right condyle was 13/16 of an inch. The average condyle path radius of the left condyle for men was 1.02 inches, and of the right condyle it was 0.87 inches. The average left condyle radius for women was 0.778 inches, and their average right condyle radius was 0.692 inches.

CONCLUSIONS

The age and sex of the patient had little bearing on the size of the condyle path angle, which was determined as approximately 35 degrees. According to the data, therefore, older patients should not be provided with cusps with less angulation simply because it is assumed that the condyle paths of these patients are less angulated. Apparently the age of the patient, at least to age 60, is not correlated with the angulation of the condyle path.

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JAW FUNCTION
Part II. Hinge Axis, Hinge Axes*

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THE MECHANICS AND STRUTURAL ANATOMY underlying functional jaw patterns have largely been ignored by dentistry, which has been engrossed with empiricism the past several decades. Exacting clinical techniques have been advanced, yet careful analysis shows the results at the occlusal surfaces to be disappointing. Conceptual knowledge of articulation lags far behind the excellence of clinical application. This situation is not only discouraging, but also no longer necessary. The remedies are at hand, and if these principles are freely disseminated and objectively acknowledged dentistry will have solved one of its major dilemmas—mechanical equivalents.

SINGLE TRANSVERSE HINGE AXIS

All conventional articulators, except those fabricated according to spherical principles, have an intercondylar hinge shaft of solid construction. In these the assumption is followed that the transverse axis is an imaginary line connecting a point in the center of one condyle with a point in the center of the opposite condyle. Thus we find that most instruments, including the Gnathoscope, the Gnatholator, the Hanau, the House, the Dentatus, the Terrell, the Stuart, and the Bergstrom Arcon, have as a common denominator one intercondylar shaft. These instruments were designed with the assumption that there is but one transverse axis of rotation; all of them are, accordingly, perfect triangles.

Unfortunately, this optimum condition does not prevail in the mandibular apparatus, which is asymmetric in shape and size, and has its condyloid processes joined at the symphysis, with no connection directly between the condyles. In addition, the condyles do not lie in a common plane of orientation. The assumption of a single intercondylar transverse axis is, therefore, open to serious question. No one challenges the idea of two vertical and two sagittal axes, so why should there not be two transverse axes?

SPLIT TRANSVERSE HINGE AXES

Page[1-4] first suggested that there are two nonintersecting transverse axes controlling rotation in the sagittal plane. He reasoned that since the mandible is asym-

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metric the condyles cannot lie in a common plane of orientation. One will be higher, lower, ahead, or behind the other, thus perpetuating the innate irregularity of the mandible. Furthermore, since the condyles are gross irregular objects and not spheres, according to mechanical axiom they cannot rotate on point centers but must instead rotate on line centers. In mechanics, only perfect spheres have point center rotation; all irregular objects have line center rotation. Since condyles are not spherical, it is evident they must possess line centers. Page's hypothesis is not only mechanically sound but is supported by known facts about mandibular asymmetries. Frank,[5] in roentgenographic studies of condylar positions, reported that no one condyle was found to be placed symmetrically in relation to its opponent. He states, "It does not seem possible that the symmetrically placed condyles of the articulator can simulate the asymmetrically placed condyles of the human being." Hinge readings which I performed on postmortem specimens also verify innate asymmetries of the mandibular bony framework This means that sagittal hinge radii from the transverse axes to a midpoint on the symphysis are unequal and that the condyles are not symmetrically oriented in a common plane.

Page is fully justified in his contention regarding mandibular and condylar irregularities, and the mechanical principles by which he explains the split or broken transverse hinge have been known for many centuries.

There has been much controversy over the idea of split transverse axes. Granger,[6] in speaking of the location of the hinge axis, says, "but if in locating this axis, one side were rotating while the other was both rotating and making a slight glide of the meniscus, the rotating side would be working on the true axis, while the point on the other side would be on a false axis, or combination axis." He infers that this would lead to what he calls the commonly held fallacy that there are two separate transverse condylar axes. He further states, "Simple geometry shows that a rigid body cannot revolve around two axes simultaneously. In order to have two condylar axes the mandible would have to bend every time it moved."[6] Apparently Granger fails to recognize that the condyles are loosely encapsulated at the temporomandibular articulation. The capsules themselves are generously folded and capable of allowing comparatively great condylar movement—protrusive translation being one good example. In addition, a rigid body *can* rotate about two axes simultaneously if those axes are in widely enough separated planes.

Granger's[7] explanation of the hinge axis concept is as follows: "In pure vertical motion it [the condyle] revolves about a horizontal axis; in pure horizontal rotation it revolves about a vertical axis. In any intermediate rotation it revolves about an axis at right angles to the plane of rotation. All of these axes meet at a point within the condyle. This is the mysterious center of rotation. When these points in the two condyles are connected by an imaginary line, it forms the hinge axis." Yet Page[8] has stated there is no known way of locating the point within the condyle where the axes meet. It is an inaccessible trigonometric function, and so becomes a mathematical impossibility. This, plus the axiom in mechanics that the various axes of rotation of all irregular objects are *line* and not point centers and that by definition they *cannot* intersect but must bypass one another, would appear to nullify Granger's statements about the center of rotation. There is no point in the condyle at which the transverse, sagittal, and vertical axes can meet in a

common intersection. If there were, we could not determine it except by mathematical coordinates. This would require surgical exposure of the joint.

A schematic mechanical equivalent of the theory of spherical or point center rotation is shown in Fig. 1. Let us connect these two spheres with a rigid U-bar and rotate the mechanism in the sagittal plane. By drawing an infinite number of circumferential tangents and dropping perpendiculars from them, we find that these tangent perpendiculars will converge at a point in the exact center of the spherical body. Moreover, during rotation of the U-bar around these point centers, a theoretical axis can be drawn between any two tangent perpendiculars which in rapid succession and for an instant would be in line during rotation. This is the principle of the ball bearing. This schematic diagram would represent a single intercondylar hinge and does represent what all hinge articulators are in essence. They are single

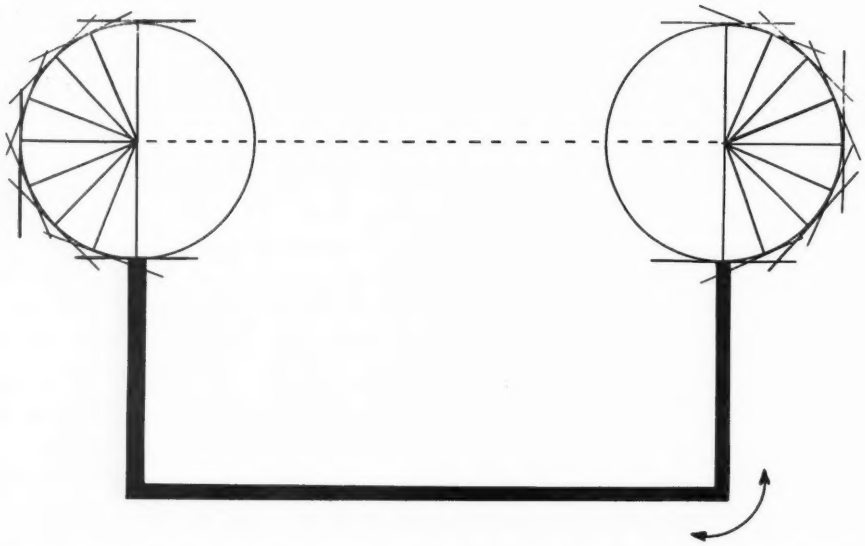

Fig. 1.—The principle of point center rotation. Infinity dictates that an intercondylar axis of rotation is always possible because of the infinite number of circumferential tangent perpendiculars successively in line during rotation in this situation.

plane, mid-sagittal opening and closing instruments, with point centers of rotation and with the single rotational plane lying at right angles to the instrument shaft.

Fig. 2 illustrates the principle of line center rotation. The asymmetric condyles are represented as irregular gross masses which resemble footballs. They have the same rigid U-bar connection, but are lying in different planes. If this apparatus is rotated in the sagittal plane, we do not have an infinite number of tangent perpendiculars converging at a common point center. Instead, we have a series of loci piercing the condyle transversely, *in line*. The result is two transverse line axes, not intersecting but parallel to each other. Since by definition the theoretical axes of rotation must be mutually perpendicular to the common plane of rotation and invari-

ably parallel, if they do not lie in the same plane they cannot intersect but must bypass. We cannot draw a common intercondylar axis between these parallel axes which lie in different planes.

Thus, the concept of intracondylar, independently oriented transverse axes has emerged. They are line and not point centers, and since they must be invariably parallel, they cannot intersect if they lie in different planes. It follows that there cannot be an intercondylar axis or shaft connecting them. That there are two is substantiated by the laws applying to rotating irregular objects, by structural anatomy, and by simple observation of hinge-bow readings. These line centers operate independently of one another, each on its own constant linear hinge radius. When they are recorded with the four other axes (two vertical and two sagittal) which in combination control all tridimensional mandibular movements, the initial stage is set for precise and accurate articulation.

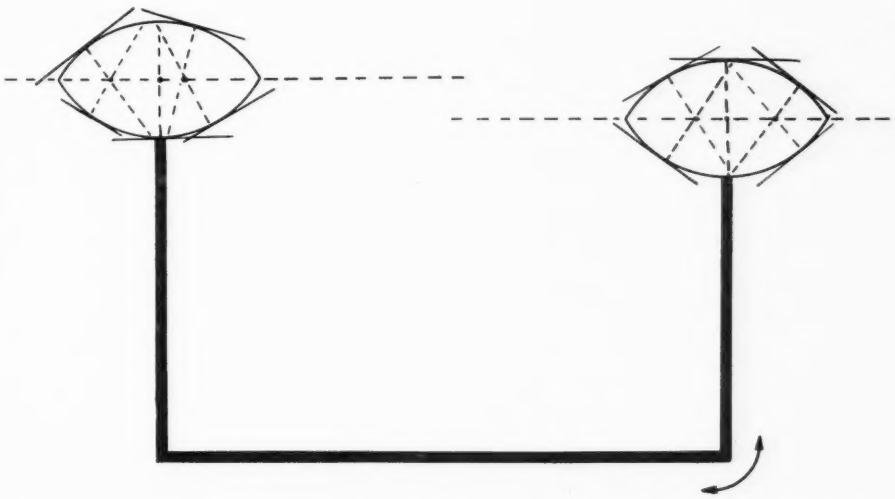

Fig. 2.—The principle of line center rotation. By definition, the line axes must be invariably parallel and mutually perpendicular to the common plane of rotation. They can never intersect but must bypass each other.

CONCLUSION

That there are certain basic mechanical laws governing rotational motion is a natural assumption in physics, engineering, and mathematics. These axioms are universally acknowledged and utilized in countless fields of human enterprise. That these same laws must also apply to the kinematics of functional jaw patterns is inherent, but their application to dental mechanics has been of comparatively recent, though valid, pertinence. Nontheless, the concepts are beginning to infiltrate dental consciousness and are pointing the way to a new and exhilarating approach to the old problem of developing articulators capable of reproducing function.

Intercondylar hinge instruments, by their very nature, are incapable of reproducing function. They possess spherical condylar inserts, they rotate on point centers, they are designed symmetrically as perfect triangles, their sagittal plane

rotational movements are confined to a single plane lying at right angles to the shaft of the instrument, and most important they all have a single intercondylar shaft of fixed linear dimension. This shaft is the original misleading flaw incorporated into all conventional articulators.

The asymmetric mandible cannot meet these idealized specifications. It is irregular in size and shape; its condyles are not spherical and they lie in dissimilar planes of orientation. In order to meet the demands attendant upon mandibular irregularities there must be two transverse intracondylar axes, each rotating on its own line center.

A new field of applied principles is emerging in dentistry, and all of our previous thoughts about jaw function will have to be re-evaluated in the light of this knowledge There are certain basic laws of mechanics governing rotational motion, and these laws are in effect as fully in dental mechanics as they are in other fields of endeavor. It is dentistry's task to find out which of these principles apply to dental mechanics, to learn to utilize them, and to let go the mass of subjective literature which passes for science in the dental field. This necessity can perhaps be best emphasized by a quotation from Norman G. Bennett,[9] where in speaking gratefully of the collaboration efforts of his brother, a mathematician, he says, "The problem is, in fact, more geometrical than anatomical, and I cannot help thinking that more frequent collaboration between workers in different fields, meeting on border-line subjects, would result in the elucidation of questions which present much difficulty to the specialist. It is one of the inherent weaknesses of specialism that its exponents must become limited to following the natural trend of their own habits of thought; and it is indeed very refreshing to find that just that aspect of a problem which presents most difficulty to the solitary worker is really only a special case of a general truth well known to a student of another branch of science."

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MANDIBULAR AND ARTICULATOR MOVEMENTS

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THE PURPOSE OF THIS STUDY was to compare the opening and closing movements of the mandible with the opening and closing movements of a hinge-axis articulator.

MANDIBULAR MOVEMENTS

A mandibular diagnostic unit was constructed to record the movements of the mandible in as simple a manner as possible. The unit consisted of a tiny flashlight bulb which was powered by a single flashlight battery and attached to a plastic chinpiece (Fig. 1). After the light was placed in position on the chinpiece, the entire bulb was coated with black enamel. Then a pin-point opening was made in the enamel so that a single beam of light was projected. The objective was to photograph the movements of the light from a side view during the opening and closing movements of the mandible.

The plastic chinpiece and light were attached to the point of the chin by silicone and adhesive paste or tape. The patient was seated in the chair (Fig. 2), and the room was darkened. The shutter of the camera was opened. The chin light was turned on, and the patient was requested to open and close his mouth just once.

The image on the film, made by the light attached to the chin, was in the form of a cycle (Fig. 3). This indicated that the mandible opened on one path and closed on another. The opening movement was slower than the closing movement, and there was some adjustment of the mandible by the musculature before it started on the closing path of the cycle.

ARTICULATOR MOVEMENTS

The opening and closing movements of the hinge-axis articulator were recorded graphically by attaching a pencil to the incisal guidepost. A pad of paper was placed in position, and the articulator was opened and closed just once (Fig. 4).

Then the light was attached to the incisal guidepost of the hinge-axis articulator. The room was darkened, the shutter of the camera was opened, the unit light was turned on, and the maxillary arm of the articulator was opened and closed just once.

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The image on the film, made by the light attached to the hinge-axis articulator during the opening and closing movements, was in the form of an arc (Fig. 5). Thus, the opening and closing movements of the articulator were along the same path, and there were no variations such as were found during the corresponding mandibular movements.

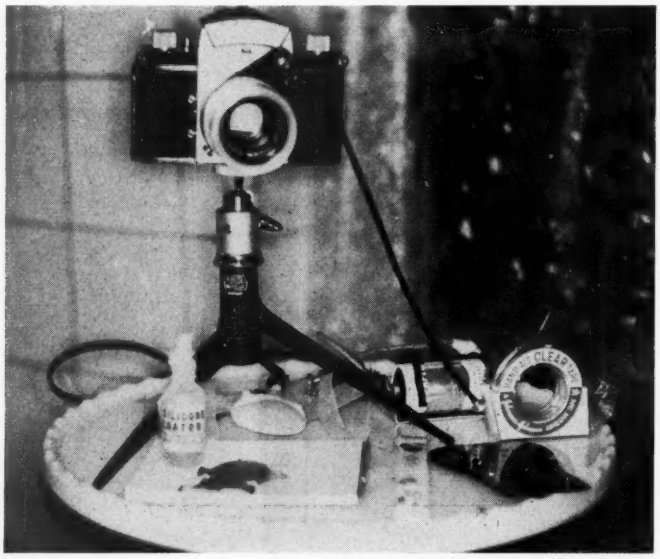

Fig. 1.—A mandibular diagnostic unit, with chin light, camera, and accessories, was used to determine mandibular movement.

Fig. 2.—The chin light is in position. The instrument in front of the mouth is a spirit level for positioning the head before the tracings are photographed.

GRAPHIC AND MATHEMATIC REPRESENTATIONS

The mandibular and articulator opening and closing movements were plotted graphically to provide a more precise representation of the differences (Fig. 6).

The basic differences between the movements which are apparent graphically can be demonstrated also mathematically. Since the mandibular opening and closing curves represent the same type of mathematical equation, the mandibular opening curve was used in comparison with the articulator curve. The values of x and y at suitable intervals were noted for each curve.

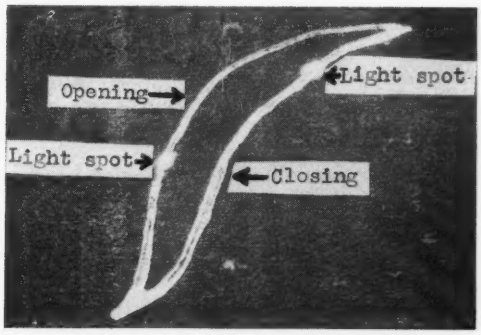

Fig. 3.—The light image represents the cyclic paths of the opening and closing movements of the mandible in the right sagittal plane. The light spots show momentary hesitations.

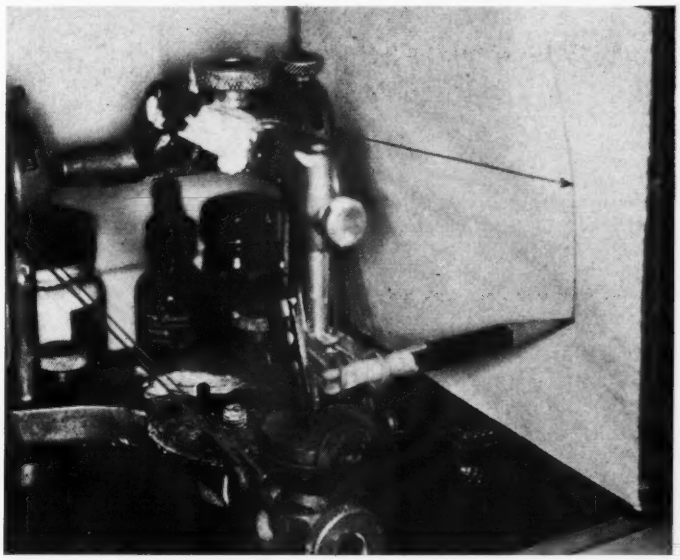

Fig. 4.—A tracing is made of the arc of the opening and closing movements of a hinge-axis articulator in the right sagittal plane.

A third-degree equation was required to express the mandibular curve, whereas a second-degree equation was sufficient for expressing the articulator curve. Mathematically speaking, the mandibular tracing is the more complex one since it is a curve with inflection, while the articulator tracing is a simple arc of a

circle. The differences between the mandibular and articulator opening and closing movements are expressed mathematically as follows:

Curve 1 (Patient)	$y = ax^3 + bx^2 + cx + d$ $y = .11x^3 - .40x^2 + .23x - .16$	Third-degree equation
Curve 3 (Articulator)	$(x - h)^2 + (y - k)^2 = r^2$ $x^2 + y^2 + 18.94x - 6.38y = .163$	Second-degree equation

The opening and closing mandibular tracings were not constant for the same patient and varied with each recording. The obvious consistency was that the mandibular tracings were complex curves that did not bear any resemblance to the

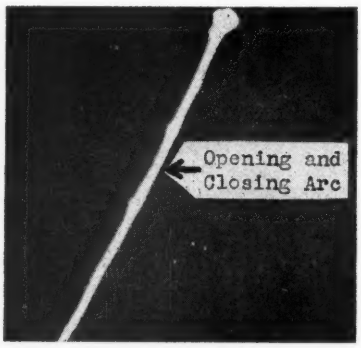

Fig. 5.—The image of the arc of light represents both the opening and closing movements of a hinge-axis articulator in the right sagittal plane.

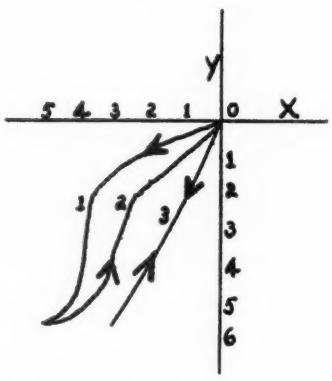

Fig. 6.—The mandibular cycle and the articulator arc tracings are plotted for comparison. *Curve 1* is the opening path of the mandible, *curve 2* is the closing path of the mandible, and *curve 3* is the opening and closing path of the articulator.

articulator tracings. Functional mandibular chewing recordings made in several planes served to increase the complexity of the tracings and to enhance the above findings.

Further studies are in progress to determine the value of individual mandibular tracings as a diagnostic aid.

CONCLUSION

The normal opening and closing movements of the mandible do not coincide with the opening and closing movements of a hinge-axis articulator.

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THE CLOSING MASTICATORY STROKES

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THE LIMITATIONS ON FACTUAL REPRESENTATION of functional mandibular movement appear almost as numerous and varied as the means of recording such movement. Each of the techniques used for this purpose has one or more of the following disadvantages: (1) interference with mastication and proprioception due to intraoral devices, (2) abnormal condyle positioning due to modification of occlusal height by the intraoral device,[1,2,3] (3) abnormal muscular activity due to weighting the mandible with intraoral and extraoral devices,[4] (4) the use of limited, simple, instructed, manipulated, and slow movements,[5,6,7] which do not occur in mastication, for the recording of arcs and pathways, (5) roentgenograms of static mandibular positions,[8,9] (6) roentgenograms made in positions other than the usual vertical masticatory positions, (7) roentgenograms and recordings made in only one plane,[10] and (8) roentgenographic recording in two planes but not simultaneously.

The most advantageous method of studying masticatory movement appears to be some form of motion radiography of the actual chewing of a bolus with small lead markers attached to the dentition. This method has none of the gross deterrents to normal function and few of the lesser disadvantages.

PRELIMINARY STUDY

The Fairchild apparatus† was employed for serial roentgenography. Two exposures were made per second with the subjects seated. Anteroposterior and lateral projections of subjects chewing walnuts were made separately. The 9½ by 10¼ inch films yielded some insight into mandibular movement. The frequent blurring of markers due to motion, however, precluded the making of uniformly satisfactory tracings.

Cinefluorography with the Philips Image Intensifier‡ provided an excellent opportunity for the study of actual function. Separate lateral and anteroposterior projections were made on 16 mm. motion picture film at 32 to 48 frames per second with the subject standing. The masticatory strokes were difficult to trace on the 16 mm. frames because of some blurring on still projection. The large

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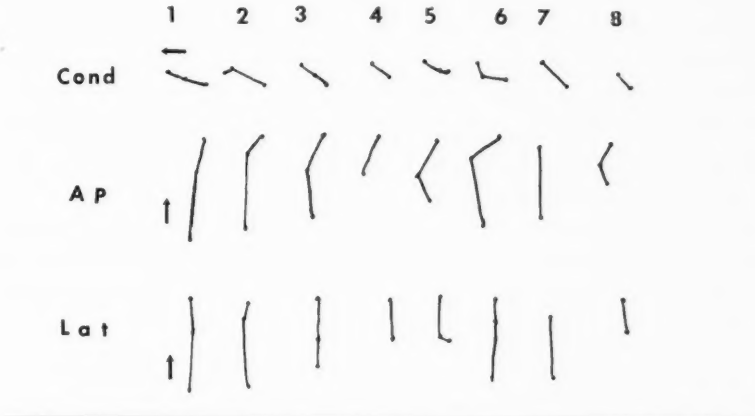
number of frames per second, however, provided a detailed view of mandibular movement.

The Schönander apparatus*[10] was used to make simultaneous anteroposterior and lateral projections of masticatory strokes. With the patient horizontal, 14 by 14 inch films were exposed at a rate of six per second with an exposure of 1/120 second. Fifty-eight films constituted a complete series. Such synchronization facilitated a determination of maxillomandibular contact in the lateral view when the cor-

Fig. 1.



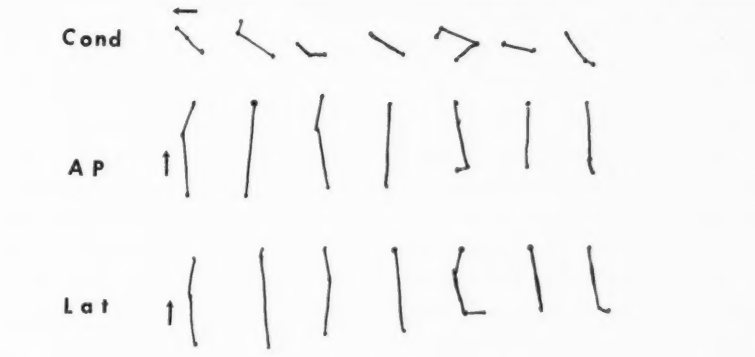


Fig. 2.

Fig. 1.—Eight closing masticatory strokes were recorded from a subject with natural teeth. Anteroposterior *(AP)* and lateral *(Lat)* projection tracings of incisal markers and lateral projections of the condyle paths *(Cond)* with corresponding strokes were made.

Fig. 2.—Seven closing masticatory strokes were recorded from a subject who was wearing a complete upper denture and a distal extension removable partial lower denture.

responding anteroposterior view indicated contact or near contact. Images on 14 by 14 inch films can be traced easily, and the sharpness of images obtained with short exposures under such conditions of rapid movement is good. Therefore, this method was used for the study of the closing masticatory strokes.

*Elema-Schönander Corp., Stockholm, Sweden.

PROCEDURE

Subjects over 45 years of age were selected because of the radiation hazards involved. None of the subjects were dentists nor were they familiar with the movements to be studied. One subject had natural teeth in good occlusion. Another had satisfactory complete upper and removable partial lower dentures. Figs. 1 and 2 show tracings of strokes of these two subjects. Another subject had new complete dentures inserted 24 hours previously. And two other subjects were experienced complete denture patients. All subjects registered the same bracing position (centric occlusion) in the horizontal position as in the vertical position. Small lead markers were attached to the upper and lower central incisors at their mesial surfaces and in the bicuspid-molar regions one hour before exposures were made. The markers were held in place with ligature wire or self-curing acrylic resin. Two test films (one in each direction) were exposed to check the positioning and exposure. A walnut meat was inserted between the upper and lower central incisors, and no special instructions were given other than to start eating on the signal. There was no manipulation of the mandible by the operator.

Following the processing of the film, the anterior markers were traced in both anteroposterior and lateral views using the other markers and natural landmarks for orientation. A template was made of the mandible and of one condyle for use where the latter became partially obscured.

OBSERVATIONS

The number of closing strokes varied from five to nine during the 4⅔ seconds of chewing which was constant for all patients. Most of the masticatory time was spent with the teeth out of occlusal contact. In the anteroposterior view, most closing strokes *appeared* to end slightly inferior to or at centric occlusion. The synchronized lateral view of this position showed lack of tooth contact in most closing stroke terminations. The mandible moved with greater speed in the opening movement than in closing movement. No protrusive or lateral excursions were observed. The closing strokes varied from one to another in length or direction, or both, in the same patient in both anteroposterior and lateral views. The speed of closure varied frequently within different segments of individual strokes. In the lateral projection there was no evidence of a uniform closing arc. The condyle paths showed variation in the same patient. The observations were similar to those made with both the Fairchild and the cinefluorographic techniques in the preliminary studies.

DISCUSSION

The technique employed in this study has limitations, particularly the use of a template to trace paths of one condyle when it enters obscured areas. The template seems more useful for tracing simple opening and closing movements. The many twisting movements which the condyle makes during function cannot be recorded adequately in one plane by this method. It does appear, however, from this study, that condyle paths can be irregular from one closing stroke to another, possibly according to the needs of the moment.

Only one type and size of bolus was used, and movements of only the beginning of mastication were recorded. However, the freedom from restriction to slow opening and closing movements, the freedom from instructed lateral and protrusive excursions, and the absence of cumbersome recording devices allow some insight into functional movement.

The proportion of the total masticatory time spent at, or just inferior to, centric occlusion appears small enough to question the importance of an exact meeting of opposing occlusal surface sliding pathways for masticatory purposes. The impression is that the opposing food table surfaces are aligned for crushing purposes and vary in alignment according to the needs of the split second.

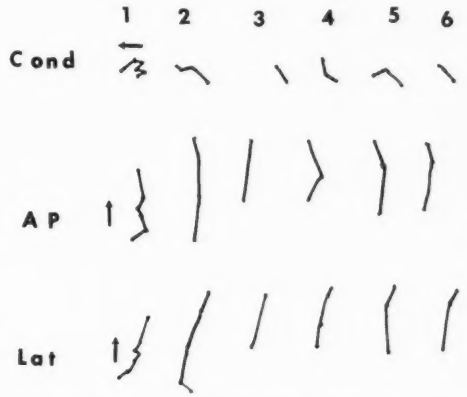


Fig. 3.—Records were made from a new complete denture wearer (24 hours' experience). This was the first attempt at chewing a solid food such as a walnut meat. The first stroke shows many short movements in various directions and occupies a full second, an unusually long time for a stroke of moderate length. Six strokes were completed.

No tooth contact was observed in incision nor was a protrusive excursion noted. The certainty that actual incision took place in all instances or that it was recorded in Figs. 4 and 5 is questioned, however, because of probable premature starts by these subjects. Tracings showed variation in length or direction, or both, from stroke to stroke for each subject.

The speed in different segments within some closing strokes varied. From a functional viewpoint, this seems understandable in view of the progressive change in size and texture of the bolus with each stroke or part of a stroke and the influence of proprioception. A constant arc of simple opening and closing movements similar to that obtained with other recording devices was not found on the lateral projections of actual mastication. Condyle paths appeared to vary from one stroke to another in the same patient.

Irregular closing strokes tended to be accompanied by irregular condyle paths. Most striking perhaps is the first stroke recorded on a subject with new complete dentures inserted 24 hours prior to the test (Fig. 3). She had worn a removable partial upper and complete lower denture previously. The first stroke required two to three times the amount of time required for subsequent strokes of comparable length. Considerable irregularity was found in both views of this stroke as well

as in the condyle path. The probable confusion in coping with a strange bolus and new dentures is reflected in the first stroke. The rapidity of muscular orientation is indicated in the second stroke which was much less irregular and traversed a longer distance in a shorter period of time.

Leisurely chewing with some long strokes appears in tracings of an experienced complete denture wearer (Fig. 4). Rapid mastication appears in tracings of another experienced complete denture wearer (Fig. 5). Many more strokes were taken during the standard mastication time; however, they were shorter in length.

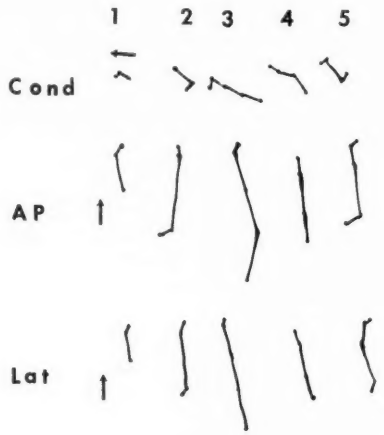


Fig. 4.—Records were made from a complete denture wearer with considerable experience. The strokes appear to be leisurely and long. Five strokes were completed.

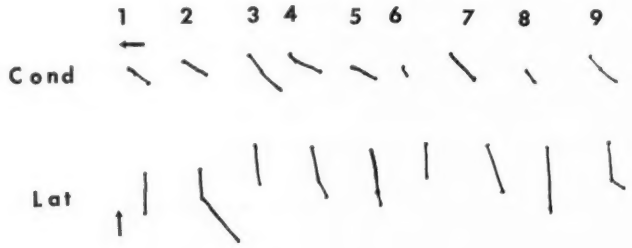


Fig. 5.—Records were made from a complete denture wearer with considerable experience. Many short rapid strokes are evident. Only the lateral projection was obtained. Nine strokes were completed.

SUMMARY

Within the limitations of this study, it appears that closing masticatory strokes vary in speed within different segments of the same stroke, that the strokes vary in length or direction or both in the same patient, and that the strokes vary from one patient to another despite the similarity of the bolus in each instance. The variation was apparent in both the anteroposterior and lateral views. The condyle paths indicated similar variations. There was no constant arc of closure, and the teeth

were not in contact for most of the masticatory time studied. The jaw position repeated most frequently appeared to be at or just inferior to centric occlusion at the end of most closing strokes. The number of closing strokes within a specific period of masticatory time varied from patient to patient.

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OCCLUSAL SURFACE CONTACTS DURING MASTICATION

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IN PREVIOUS STUDIES, it was found that contact of the occlusal surfaces occurred during mastication, regardless of the type of posterior tooth form used or the arrangement of the occlusal scheme.[1] The objective in this study is to ascertain specific areas of occlusal surface contact on the right first mandibular molar of complete dentures during mastication.

TEST DENTURES

A 33-year-old man was selected for the study. He had worn complete dentures satisfactorily for approximately four years. The clinical and roentgenographic findings revealed no apparent evidence of pathologic conditions. The patient had prominent ridges, normal ridge relations, and an average interarch distance. Three complete dentures were fabricated.

Two of the complete dentures were constructed using monoplane posterior teeth* arranged to an occlusal scheme that was horizontal both frontally and sagittally. The mandibular posterior teeth were arranged slightly lingual to the crest of the mandibular ridge.

The third set of complete dentures were constructed using a cusp posterior tooth form.† The second molars were deliberately excluded from this arrangement. The posterior occlusal scheme was arranged with a compensating curve frontally and sagittally. The tooth-ridge placement was such that a line drawn through the central fossa of the mandibular teeth would be slightly lingual to the crest of the ridge.

The dentures were constructed on a Hanau Model H articulator. A face-bow was used to relate the maxillary cast to the condylar elements. The condylar elements were set at zero for the dentures with horizontal occlusion. A horizontal incisal guidance was used for all test dentures. Average readings obtained from four interocclusal protrusive wax records were used to set the condylar guidances for the cusp tooth dentures. All dentures were processed in methyl methacrylate resin and remounted on the articulator for correction of processing errors. Uniformly soft interocclusal wax records were used to mount and remount the mandibular dentures in centric relation.

The opinions or assertions contained herein are those of the author and are not to be construed as official or as reflecting the views of the Navy Department or the Naval Service at large.

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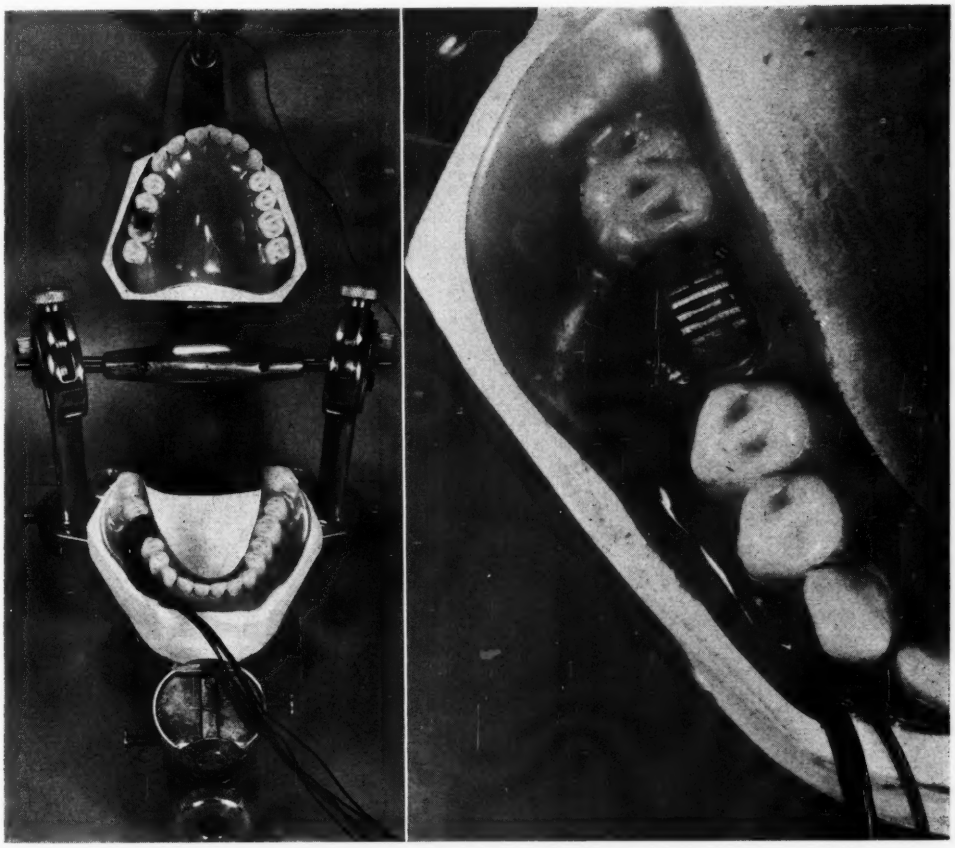
*Justi zero-degree teeth, mold 32Z.

†Justi anatomic posterior teeth, mold 32M.

Monoplane Tooth Form.—

Test dentures No. 1 (Fig. 1): The maxillary denture was modified in the following manner. A square occlusal preparation of sufficient depth was made in the right first maxillary molar to receive a wired brass assemblage. The assemblage consisted of two pieces, a square nutlike threaded outer piece and a spring screw. The spring screw consisted of a pointer with a compression spring behind it. The compression spring allowed the pointer to be depressed under the load and to



A. *B.*

Fig. 1.—*A*, The test dentures No. 1 are wired to determine occlusal contacts during mastication. *B*, The series of individually wired plates are inserted in the right first mandibular molar.

be extruded when unloaded. The wire emerged from the buccal aspect of the first molar to avoid occlusal interference. The brass assemblage was inserted in the prepared recess of the right first maxillary molar, adjusted so that the pointer would protrude beyond the occlusal plane 0.5 mm., and made secure with sticky wax.

A preparation that included the entire occlusal surface was made in the right first mandibular molar, leaving a shell of the remaining tooth. A prefabricated

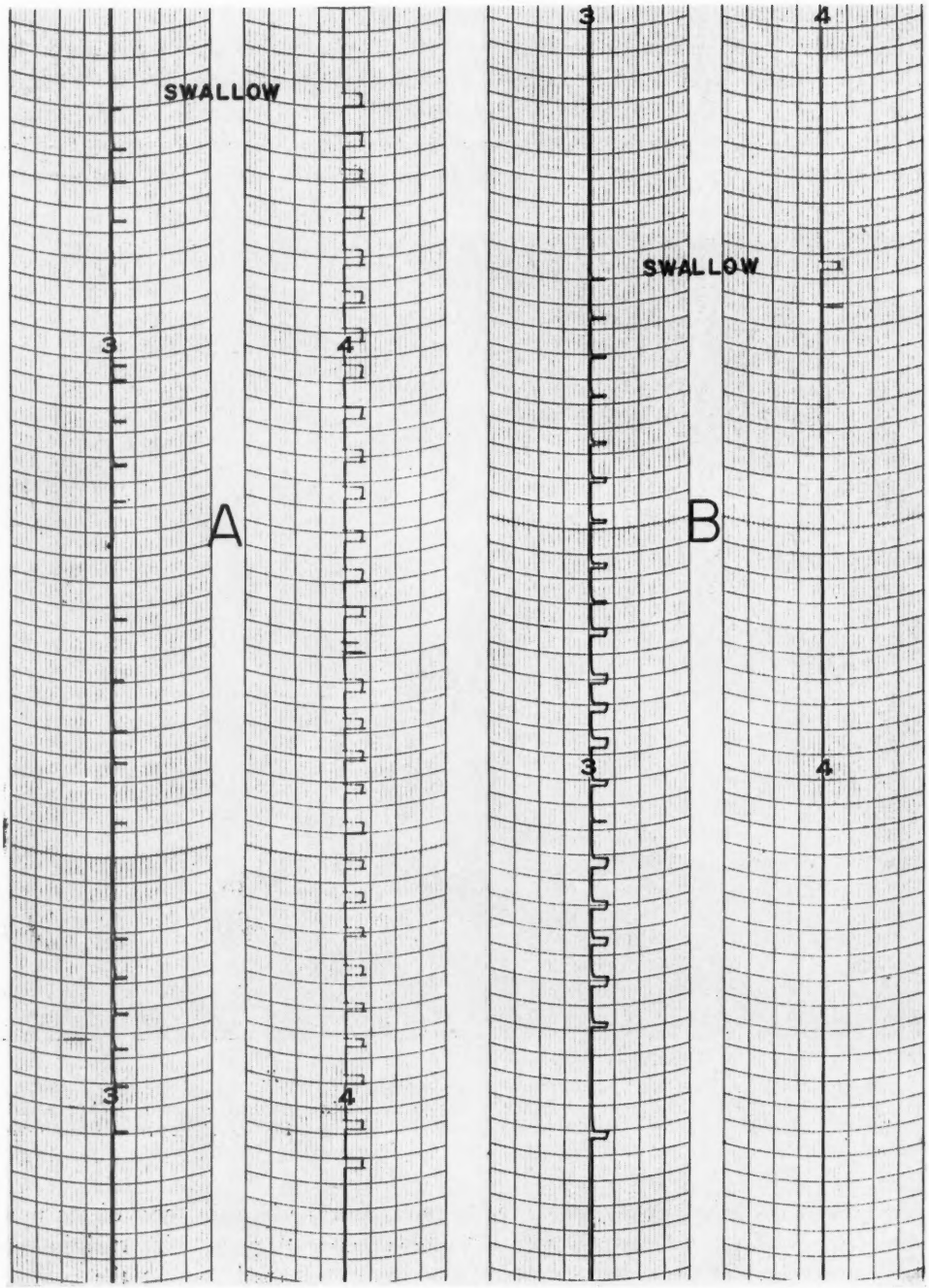
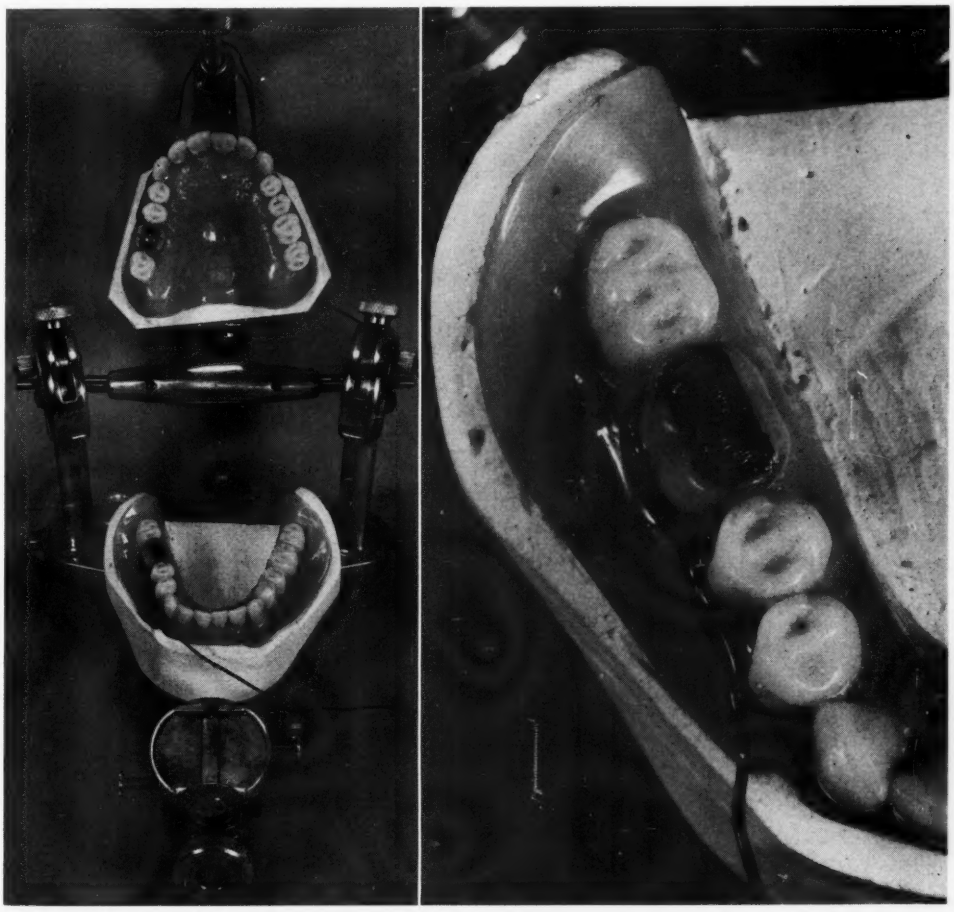


Fig. 2.—Tracings obtained on a Brush recorder while the subject was chewing peeled apple. *A*, The contacts made on plates three and four when the subject chewed on the left side. *B*, The contacts made when the subject chewed on the right side.

unit of six individually wired bronze plates, 0.48 mm. thick, was placed and made secure in the prepared recess with sticky wax. The plates were separated from each other by dielectric material, 0.5 mm. thick.

The electronic circuit consisted of a 1½ volt dry cell battery, suitable resistors, amplifiers, and a multichannel Brush recorder. Positive contact of the maxillary pointer with any of the bronze plates was manifested by a deflection on the recorder (Fig. 2).



A. *B.*

Fig. 3.—*A*, The test dentures No. 2 are wired to determine occlusal contacts during mastication. *B*, A coil of nichrome wire is positioned in the right first mandibular molar.

Test dentures No. 2 (Fig. 3): The maxillary denture was modified in the same manner as test dentures No. 1.

The right first mandibular molar was prepared similarly, except that a coil of insulated nichrome wire was inserted in the preparation. The coil was made by winding insulated nichrome wire, which had a resistance of 8 ohms per foot, over a

small rectangular piece of dielectric material. The wire emerged from the distobuccal aspect of the molar tooth and was made secure with sticky wax. The occlusal surface was sandpapered gently to remove the insulation of the nichrome wire.

A two-arm bridge electronic connection circuit was established with suitable resistors, amplifiers, and a Brush recorder. Deflections of varying heights were produced by contact of the maxillary pointer on the coil. The variation in deflection heights was due to the amount of resistance encountered in the coil in completing the circuit. Calibration studies were made by completing the circuit for each coil and noting the height of the deflections produced (Fig. 4). Distances between the coils could then be measured easily.

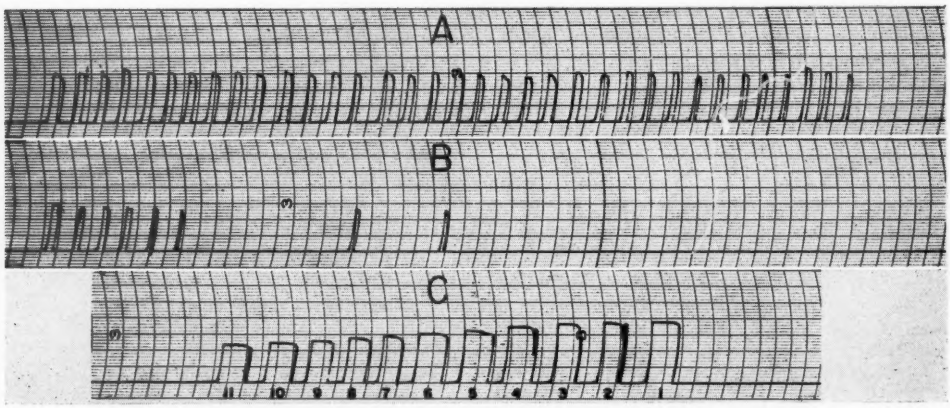


Fig. 4.—The tracing obtained on a Brush recorder while the subject chewed peeled apple, *A*, The deflections made when the subject chewed on the left side. *B*, The deflections made when the subject chewed on the right side. *C*, The known deflection heights used to determine when the coils contacted.

Cusp Tooth Form.—

Test dentures No. 3 (Fig. 5): The posterior occlusal surfaces of the right second premolar and the first molar were wired and rendered electroconductive in a manner described in a previous study.[1] Six occlusal preparations were made on the right first mandibular molar in widely separated areas. Three were on the buccal cusps, one in the central fossa, and the remaining two on the lingual cusps. Denuded ends of insulated wire were inserted in each of the preparations and made secure with amalgam. The wires emerged from the buccal aspect of the tooth and were made secure with sticky wax.

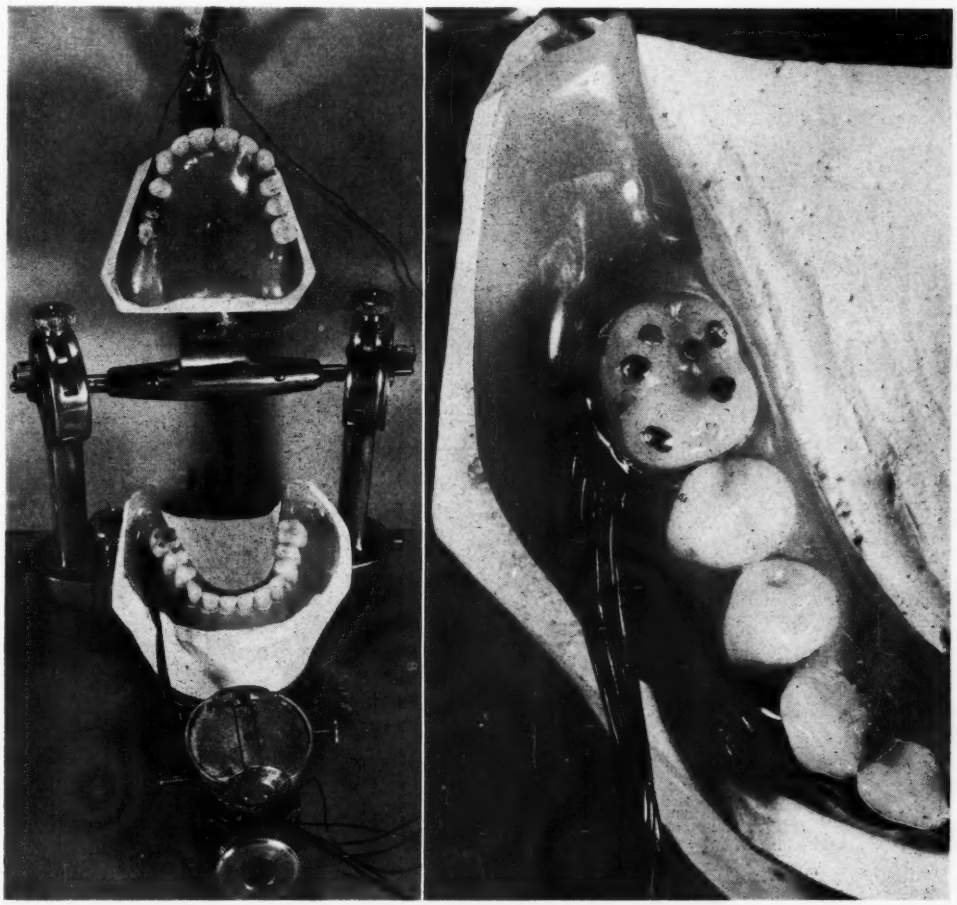
The electronic circuit was similar to that described for the monoplane tooth form dentures No. 1. Positive contact of any of the prepared restorations with the electroconductive maxillary occlusal surface caused one or more deflections on the recorder (Figs. 6 and 7).

TESTING PROCEDURES

The dentures were studied for occlusal surface contact at the right first mandibular molar during the mastication of test foods while the subject chewed on

either the left or right side of the mouth. The test foods were 3 Gm. portions of peanuts (cocktail, salted) and sections of peeled apple (Delicious variety).

The subject was instructed to chew the food on the left side of the mouth (his preferred side). The occlusal contacts were recorded on the Brush recorder. The subject was instructed to swallow whenever it was necessary and to indicate the interval of swallow by a nod of the head. He was not permitted to observe the recorder during the testing procedures.



A. *B.*

Fig. 5.—*A*, The test dentures No. 3. These cusp tooth form dentures were used to determine specific areas of occlusal surface contacts on the right first mandibular molar. *B*, The six amalgam restorations in the right first mandibular molar.

When a bolus of food had been completely masticated and swallowed, the subject was instructed to close in centric relation and gently tap the dentures together. Then he chewed a similar portion of the same test food on the opposite side of the mouth. This procedure was repeated alternately with each of the test foods for each

set of dentures. The number of masticatory strokes necessary to masticate the test foods was counted by the subject and recorded. Recordings were obtained and the data were compiled.

The three sets of dentures were tested for contact on the articulator in centric and eccentric excursions, and recordings were made for comparative study.

SUMMARY OF FINDINGS

Monoplane Tooth Form.—

Test dentures No. 1: The average number of strokes (from 14 recordings) necessary to masticate peanuts on the left side was 33.07 strokes. The maxillary

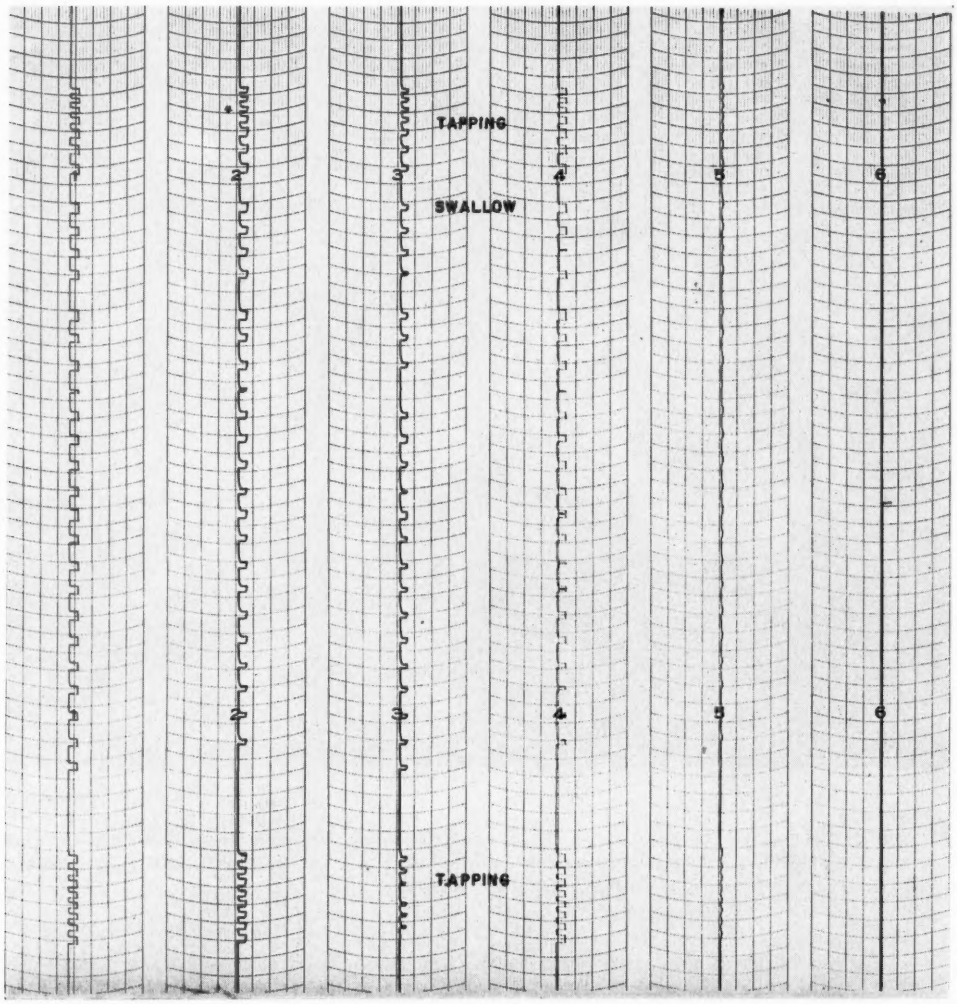


Fig. 6.—The tracings made when the subject chewed apple on the left side indicate the contacts made by the teeth.

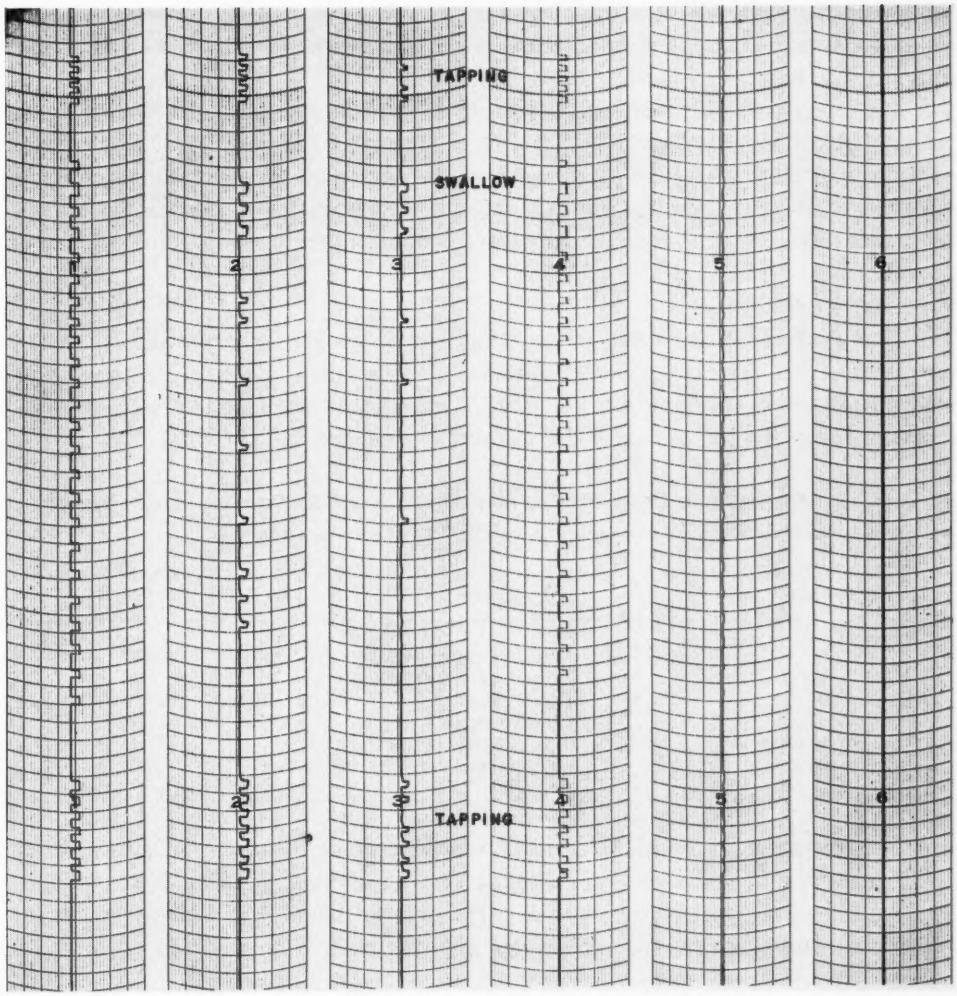


Fig. 7.—The tracings made when the subject chewed apple on the right side indicate the contacts made by the teeth.

pointer made contact with plate three on the right first mandibular molar 75 per cent of the time and plate four 98 per cent of the time.

The average number of strokes (from 10 recordings) necessary to masticate peanuts on the right side was 28.20 strokes. The maxillary pointer made contact with plate three 71 per cent of the time and plate four 23 per cent of the time. On the basis of the recordings, it appeared that the masticatory stroke on the chewing side had a horizontal protrusive component in a narrow occlusal range of approximately 0.5 mm.

Test dentures No. 2: The average number of strokes (from 12 recordings) necessary to masticate peanuts on the left side was 38.17 strokes. The maxillary

pointer on the right side made contact with the "centric relation coil" 70 per cent of the time, and made contact anterior to centric relation 9 per cent of the time and posterior to it also 9 per cent of the time.

The average number of strokes (from 2 recordings) necessary to masticate peanuts on the right side was 29.32 strokes. The maxillary pointer made contact with the centric relation coil 6 per cent of the time; 24 per cent of the contacts recorded were anterior to centric relation. On the chewing side, the findings indicated that there was a horizontal, protrusive component in the masticatory stroke of approximately 0.5 mm.

Cusp Tooth Form.—

Test dentures No. 3: The average number of strokes (27 recordings) necessary to masticate peanuts on the left side was 29.15 strokes, and on the right side (5 recordings) 24.00 strokes were necessary. Occlusal surface contacts with the restorations in the right first mandibular molar are presented in Table I.

TABLE I. APPROXIMATE PER CENT CONTACT ON THE RIGHT FIRST MANDIBULAR MOLAR

CHEWING PEANUTS RIGHT SIDE	RESTORATION	CHEWING PEANUTS LEFT SIDE
66	Mesiobuccal cusp	100
0	Distobuccal cusp	67
0	Distal cusp	82
66	Central fossa	76
0	Mesiolingual cusp	0
0	Distolingual cusp	19

The average number of strokes (17 recordings) necessary to masticate peeled apples on the left side was 18.00 strokes, and on the right side (12 recordings) 21.20 strokes were necessary. Occlusal surface contacts with the restorations on the right first mandibular molar are presented in Table II.

TABLE II. APPROXIMATE PER CENT CONTACT ON THE RIGHT FIRST MANDIBULAR MOLAR

CHEWING APPLE RIGHT SIDE	RESTORATION	CHEWING APPLE LEFT SIDE
98	Mesiobuccal cusp	100
36	Distobuccal cusp	93
12	Distal cusp	82
79	Central fossa	78
0	Mesiolingual cusp	0
8	Distolingual cusp	13

CONCLUSIONS

The findings indicate that the occlusal contacts established on the articulator did not coincide with the occlusal contacts made during the functional movements in the mouth.

There is evidence that on the chewing side there is a horizontal, protrusive component in the masticatory strokes. For this subject, the occlusal contacts were found to be predominately in centric relation on the nonchewing side.

Additional studies which include a larger number of subjects are needed.

I wish to acknowledge my indebtedness to J. C. Thompson, R. K. Logan, and others of the U. S. Navy Electronics Laboratory, San Diego, Calif., for their generous cooperation in providing invaluable technical assistance; and to C. E. Laue (DT1) USN, of the U. S. Naval Training Center, San Diego, Calif., for assisting in the fabrication procedures.

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THE STRUCTURE OF THE MOUTH IN THE MANDIBULAR MOLAR REGION

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Though many other workers have discussed the mandibular molar region, there is still disagreement about the arrangement of its parts and the structures that can be identified in the living mouth. A series of dissections, now preserved in the Faculty of Medicine, Baghdad, Iraq, has been prepared to clarify these points. This article is limited to the mandibular molar region where teeth are present. A subsequent article will deal with the edentulous condition. The literature will be discussed with the dissections.

SURFACE ANATOMY

Fig. 1 shows the right side of the mouth of a strongly built, fleshy man. The tongue is pulled aside, but otherwise the mouth is undisturbed. Between the gum and the tongue, the mucous membrane lines the alveololingual sulcus ("sublingual fossa") with its sublingual fold. Posteriorly, the sulcus continues into the retromylohyoid space, described by Edwards and Boucher[1] as extending to the palatoglossal fold (anterior pillar). Posterior to the last molar tooth is a small mass of fibrous tissue, the retromolar papilla, and above and behind this is a soft rounded mass, the retromolar pad. The pad may be so prominent as to overhang the papilla. It is supported below by the lingual tuberosity of the mandible, which is a bony prominence of the mandible from which the most posterior fibers of the mylohyoid muscle arise (see Fig. 10). Between the retromolar pad and the palatoglossal fold is the shallow prefaucial fossa forming the posterosuperior part of the retromylohyoid space. In this fossa, a soft elevation made by the anterior border of the medial (internal) pterygoid muscle can be distinguished. Above the pad lies the hamular region of the soft palate.

THE STRUCTURES COVERED BY THE MUCOUS MEMBRANE

Removal of the mucous membrane from the soft palate exposes the palatine glandular mass (Fig. 2). This mass has a retromolar extension which forms the retromolar pad. Sicher[2] gives a composite histologic drawing showing the glandular structure of the pad, but, as the mandible and retromolar pads were removed from his specimen, he does not show the retromolar extensions of the palatal mass. We

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agree with Edwards and Boucher[1] in considering the glands as part of the palatal system rather than as a separate group. Swenson[3] shows this continuity, but without label or comment.

The lingual nerve emerges between the mylohyoid and medial pterygoid muscles and from under cover of the superior constrictor muscle (in medial view). It crosses obliquely the suboral space of Mohiuddin and Martin[4] which underlies the alveololingual sulcus. Here the nerve lies on the upper surface of the mylohyoid

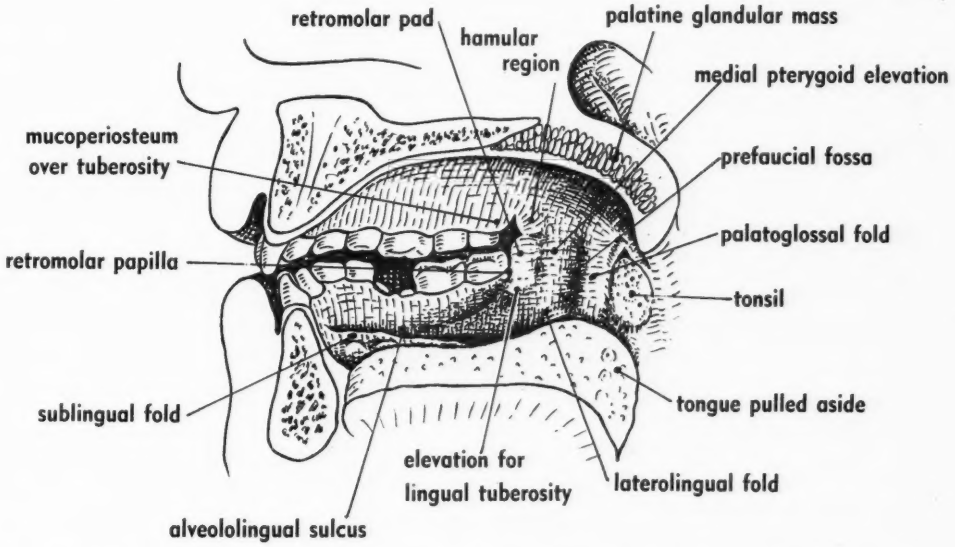

Fig. 1.—Mucous membrane of the mouth in medial view with the tongue displaced to show the alveololingual sulcus, retromylohyoid space, and retromolar pad.

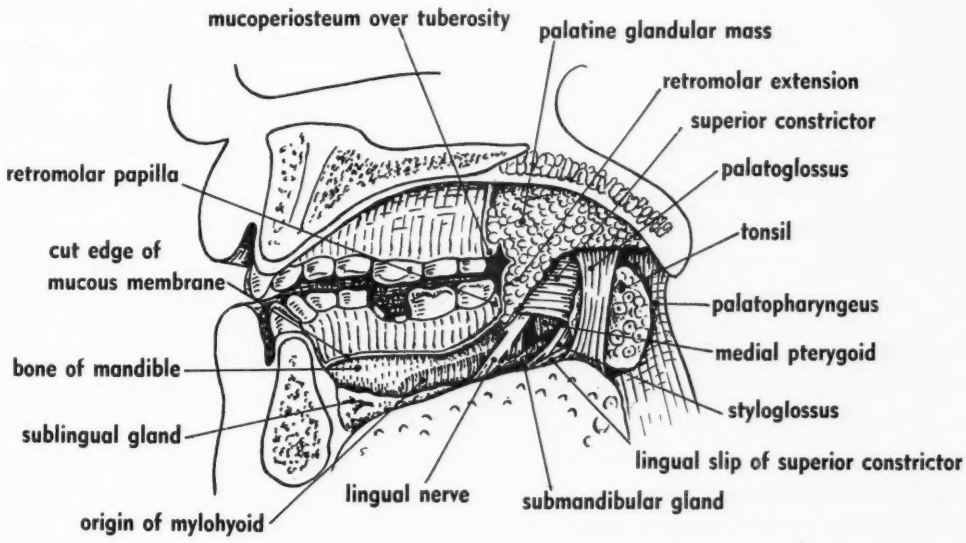

Fig. 2.—The same subject. The mucous membrane removed to show the palatine glandular mass and its retromolar extension.

muscle, giving a branch to the gum and making connections with the submandibular ganglion. A small area of the medial pterygoid muscle is exposed between the submandibular gland and the superior constrictor.

Posteriorly, the tonsil projects into the prefaucial fossa between the palatoglossus and styloglossus muscles. As the styloglossus muscle reaches the tongue, it is joined on its medial surface by the lingual fibers of the superior constrictor muscle. In the tongue, most of the fibers of the styloglossus muscle follow the lateral border, but some pass medial to the hyoglossus muscle to reach the median plane.[5]

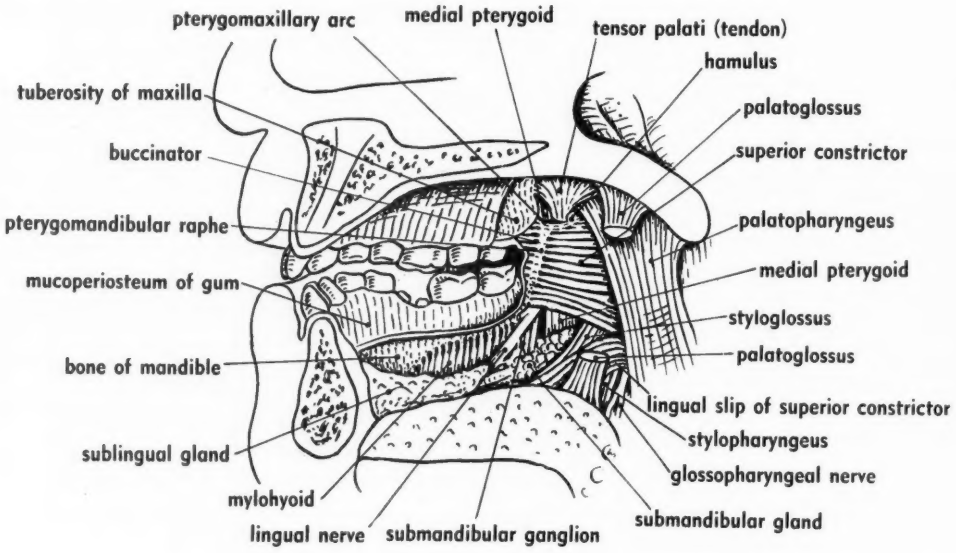

Fig. 3.—The same subject. Deeper dissection to show the pterygomandibular raphe and the origin of the superior constrictor muscle with its lingual slip.

THE MUSCULAR BACKGROUND

Removal of the palatine glands with their retromolar extensions and further displacement of the tongue, after cutting the palatoglossus muscle, exposes the muscular wall of the mouth more fully (Fig. 3). A narrow fibrotendinous pterygomaxillary arc, convex downward, connects the tuberosity of the maxilla and the hamulus of the pterygoid plate, arching under the tendon of the tensor palati muscle as it turns round the hamulus. This arc is said by Sicher[2] to be attached to the pyramidal process of the palatine bone, but we, in agreement with Last,[6] have found it as shown in our figure crossing the anterior fibers of the medial pterygoid muscle to reach the tuberosity of the maxilla.

From the convexity of the arc the pterygomandibular raphe runs to the mandible, with the buccinator and superior constrictor muscles attached to it, to the arc, and to the bones near the attachments of the arc and the raphe (see Fig. 11). The raphe is a soft, stretchable structure; the arc is inextensible and ligamentous. The fibers of the raphe run horizontally across its breadth and not along its length

as in a ligament; nor, as shown in many textbooks, do they project above the general muscular surface. So, again with Last,[6] we prefer to retain the old term, "raphe," rather than the official "ligament."

The retromolar pad covers the lower end of the raphe and the jaw nearby and spreads onto the origins of the buccinator and superior constrictor muscles. An oblique section through the retromolar pad (see Fig. 8) shows the relation of this pad to the bone of the mandible at the attachments of the pterygomandibular raphe and the buccinator and superior constrictor muscles with the lingual nerve about

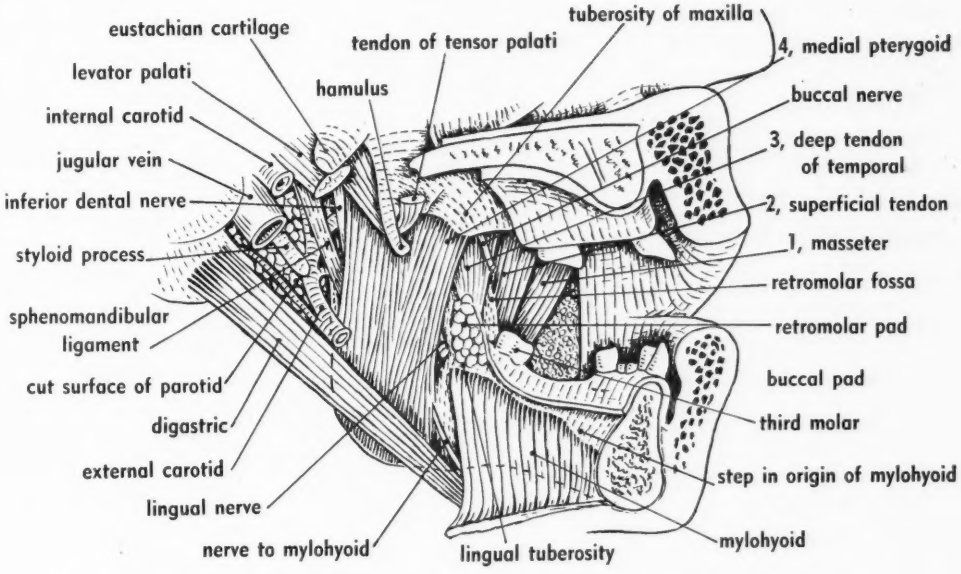

Fig. 4.—The muscles related to the jaws with the main musculotendinous structures.

to emerge from under cover of the constrictor. Fish,[7] quoting work by Garmany, describes and figures in this position another muscle, his "lingual slip of the superior constrictor," said to have an extensive origin from the mandible and an insertion into the tongue. We have found no trace of any such muscle in our dissections. In fact, a slip of muscle which arises medially to the insertion of the styloglossus muscle passes from the tongue to the lower border of the superior constrictor muscle. This has long been known and is shown in Fig. 3. Sometimes it is described as a separate muscle, the glossopharyngeus,[8] and sometimes as a lingual slip of origin of the superior constrictor. It is figured clearly in *Gray's Anatomy* (1938 edition, Fig. 1150, redrawn for later editions) and in meticulous detail from several aspects by Pernkopf.[9] But this slip has no attachment to the jaw, and it does not cross between the mandible and the tongue.

The Muscles of Mastication.—The oral surfaces of the masticatory muscles are seen best in preparations fixed with the mouth open, so that they can be dissected from the medial aspect. After removal of the buccinator and superior constrictor muscles, four musculotendinous masses are exposed as they are attached to the mandible (Fig. 4). Lying in order from before backward and from without inward, they

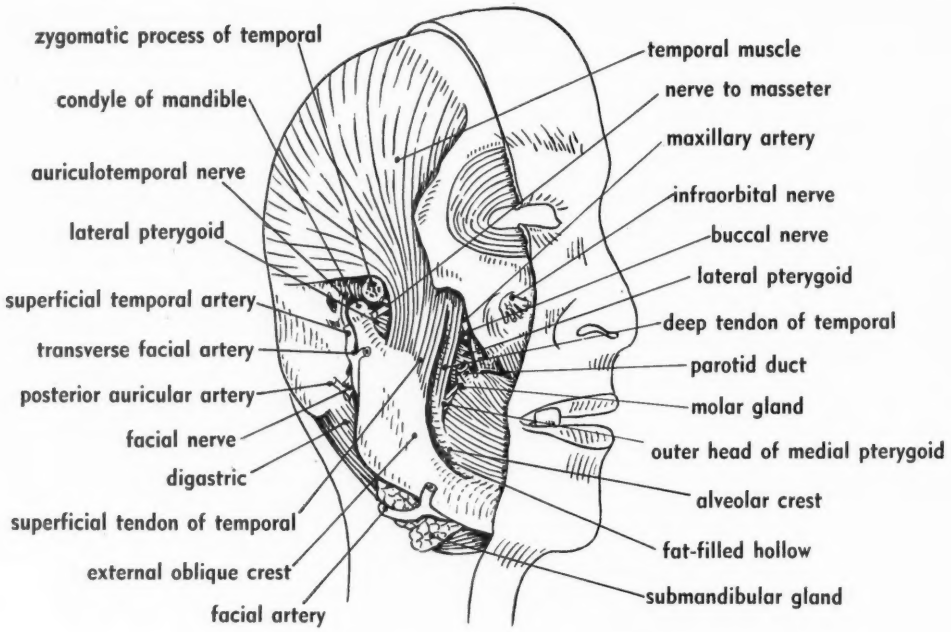

Fig. 5.—A half head in oblique view to show the insertions of the temporal muscle.

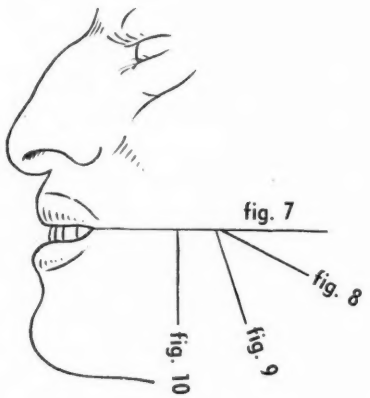

Fig. 6.—The positions of the sections shown in Figs. 7 to 10.

are: (1) the masseter, (2) the superficial insertion of the temporalis, (3) the deep insertion of the temporalis, and (4) the medial pterygoid muscle. The two tendons of the temporalis and the bare bone between them, which forms the retromolar fossa of the mandible, are figured and described in detail by Sicher.[2] From the outside, however, they are seen particularly well (in an oblique lateral view) in a preparation from a subject whose molar and premolar teeth had been lost (Fig. 5). The deep head cannot be seen in direct lateral view, and in standard anatomy textbooks it is poorly described.

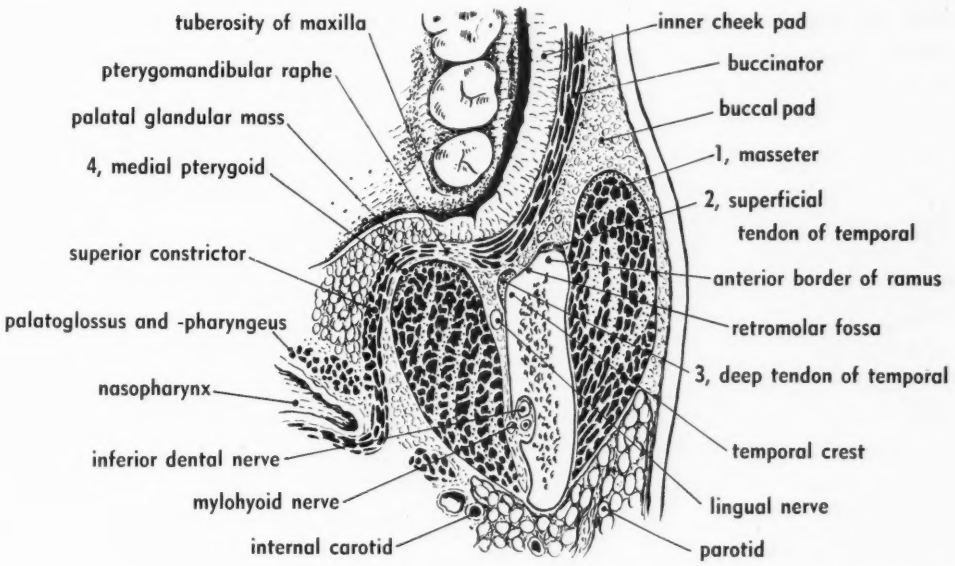

Fig. 7.—Horizontal section through the mouth showing the S-shaped curvature of the buccinator-constrictor sheet and its relation to the musculotendinous structures.

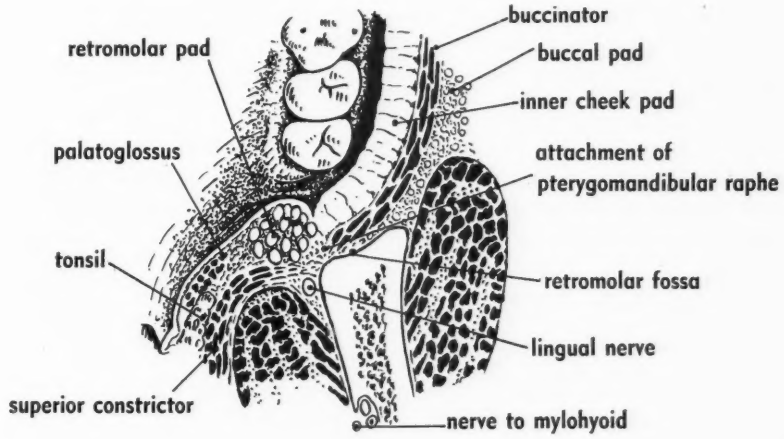

Fig. 8.—Oblique section through the retromolar pad showing it resting on the attachments of the buccinator and superior constrictor muscles to the mandible.

A horizontal section (Fig. 7) again shows the four musculotendinous masses. These are covered on their anteromedial surfaces by the buccinator muscle, the pterygomandibular raphe, and the superior constrictor muscle, which together form a thin, doubly-curved, musculofibrous sheet (Fig. 8). In the living subject all four major masses can be palpated—the masseter muscle when the teeth are clenched, the outer tendon of the temporal muscle when the masseter muscle is relaxed, the

inner tendon when the mouth is opened to admit the finger behind the last molar, and the anterior border of the medial pterygoid when the mouth is opened widely to stretch the muscle.

Edwards and Boucher[1] and Craddock[10] state that the retromolar fossa of the mandible and its borders are palpable in the living subject, implying that the tendons of the temporalis muscle attached to the borders can be defined; but we have found no direct statements on this point in the literature.

Most authorities give the pterygomandibular raphe as the main palpable structure of the region and do not mention the medial pterygoid muscle. Thus, Sicher[2] describes it as a "tendinous band" which "elevates a fold of mucous membrane and is especially prominent if the mouth is widely opened." In our dissections, the raphe is not palpable even when the mucous membrane over it has been removed and may even be difficult to find on dissection.

In the living mouth the pterygomandibular fold[2] can usually, but not constantly, be seen passing diagonally downward and outward from the pterygoid to the mandibular region where it fades away into the retromolar pad (see Fig. 13). In some people the fold may be sharp edged and very prominent. It loses its distinctness as the mouth is closed, and we have not been able to distinguish it in the cadaver. On palpation the sharp edge of the fold is found to be soft, easily deformable, and movable from side to side, but it overlies a hard rounded mass, not easily deformable or displaceable, the anterior border of the medial pterygoid muscle. The whole formation is usually referred to as the pterygomandibular raphe, the only structure said to be palpable in this region, but no evidence for this identification is offered apart from a general correspondence in position.

The formation may be compared to the web attaching the thumb and index finger. The adductor pollicis crosses the gap and, when the thumb is abducted, its free margin is palpable as a firm, rounded structure. At the same time, the skin over it is drawn up into a sharp edge, not firmly attached to the underlying muscle, and is easily displaceable. In the mouth the buccinator muscle, the raphe, and the superior constrictor muscle, with the attached oral mucous membrane, form a continuous sheet overlying the border of the medial pterygoid muscle, and when the mouth is opened widely this sheet is drawn up into a sharp edge. Whether or not the raphe lies along the edge cannot be determined, and the relationship may be inconstant. The thin raphe cannot possibly form the firm base of the prominence, in which the medial pterygoid muscle can always be palpated.

The Mylohyoid Muscle.—In Fig. 4 the following points were seen. The most posterior part of the mylohyoid muscle arises from the lingual tuberosity, just below the retromolar pad. Further forward, in the molar region, it is near the attachment of the mucous membrane to the mandible. In the premolar region the attachment drops suddenly to a lower level, giving a distinct step in the line of origin.

An almost coronal section in the plane of the third molar (Fig. 9) cuts the posterior end of the mylohyoid muscle. This shows the fibers passing almost vertically downward from their attachment on the lingual tuberosity. The muscle is partly tendinous at its origin, and this part arises from the mylohyoid line. The upper layer is fleshy and arises from a smooth area above the line. Mohiuddin and Martin[4] show

the origin correctly, though they do not mention the tendon. Most authors describe the muscle as attached to the line alone. The section also passes through the posterior end of the alveololingual sulcus, and shows the folding of the mucous membrane between the tongue and the mandible and the structures that lie in the floor of the fossa.

A coronal section through the second molar (Fig. 10) passes through the tendon of the mylohyoid in the region of its maximum development, and shows the muscle passing into the floor of the suboral space.

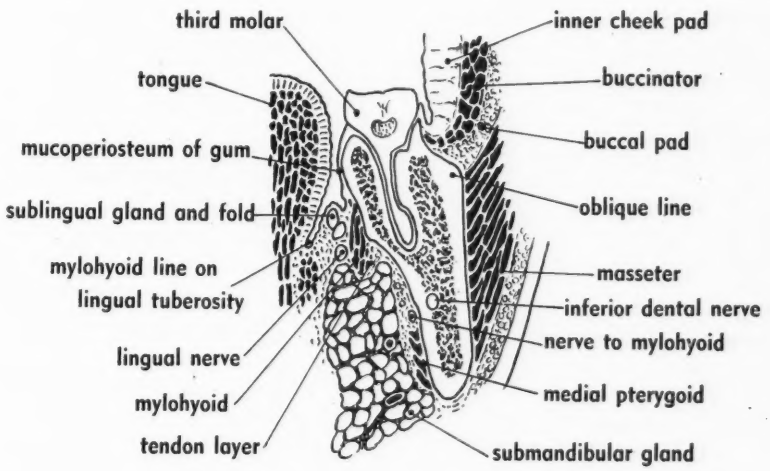

Fig. 9.—Oblique section through the third molar showing the lingual nerve separated from the lingual tuberosity of the mandible by the mylohyoid muscle.

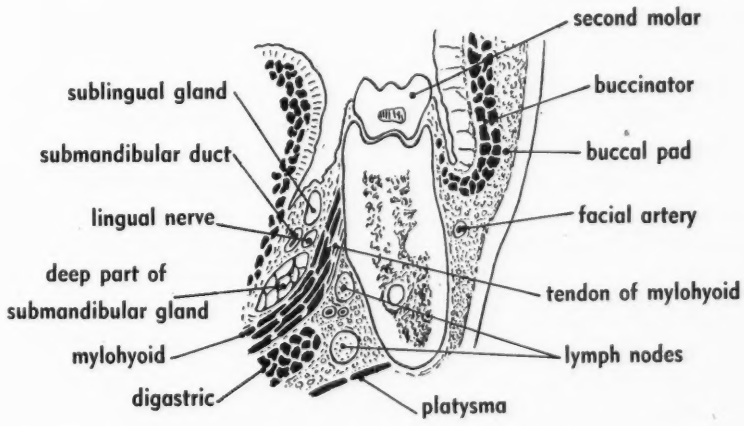

Fig. 10.—Vertical section through the second molar showing the incurved attachment of the buccinator muscle to the mandible.

The Buccinator Muscle.—In lateral view (Fig. 12) the buccinator appears as a simple rectangular muscle with fibers which run posteroanteriorly. Coronal sections through the molar region (see Figs. 9 and 10) show a C-shaped structure. The upper and lower margins of the muscle are rolled inward to take origin from the buccal alveolar crests of the maxilla and mandible very near the line of separation of the mucous membrane and periosteum, that is, about halfway between the necks of the teeth and the apices of their roots. This inturned arrangement allows a muscle 4 cm. wide to have its bony attachments only 3 cm. apart when the mouth is closed. This means that each fiber coming from one or other of the alveolar borders has to wind round the appropriate limb of the C as it passes forward to the angle of the mouth.

Further, owing to the S-shaped curvature of the buccinator-constrictor sheet in horizontal section, shown in our Fig. 7 and Sicher's[2] Fig. 277, the outer surface of the pterygomandibular raphe comes to look posterior rather than lateral, so that the posterior border of the buccinator is difficult to expose from the face. In these circumstances it is hardly surprising that the various accounts of the attachments of the buccinator are discrepant. Sicher[2] shows it attached to the floor of the retromolar fossa, which would place it between the two tendons of the temporal muscle; and it is occasionally illustrated outside the external oblique line,

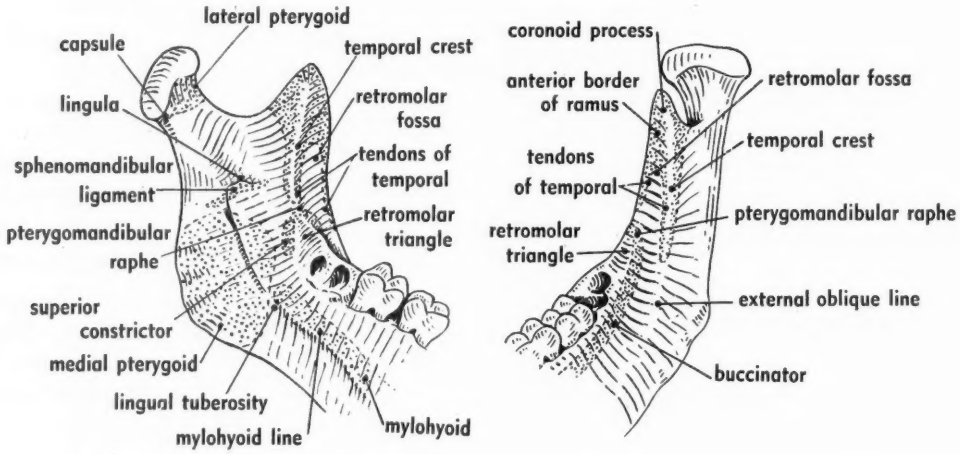

Fig. 11.—Markings on the mandible. The ramus in medial and oblique anterolateral view.

which would put it lateral to both tendons. In fact, it is anteromedial to both tendons (see Fig. 7), and after leaving the pterygomandibular raphe, the origin follows the outer border of the retromolar triangle to the buccal alveolar crest of the molar teeth. Edwards and Boucher[1] show this origin correctly at the medial margin of their "buccal shelf," the area between the external oblique line and the alveolar crest. The inner surface of the buccinator muscle carries a thick, resilient coating, forming the inner cheek pad, comparable in thickness to the buccal pad of fat on its external surface.

BONY ATTACHMENTS

Sicher[2] has given an admirable description of the mandible and his terminology will be employed here. The anterior border of the ramus (Fig. 11), on which the superficial tendon of the temporal is inserted (see Fig. 4), is continued into the external oblique line. The border is separated from the temporal crest by the retro-

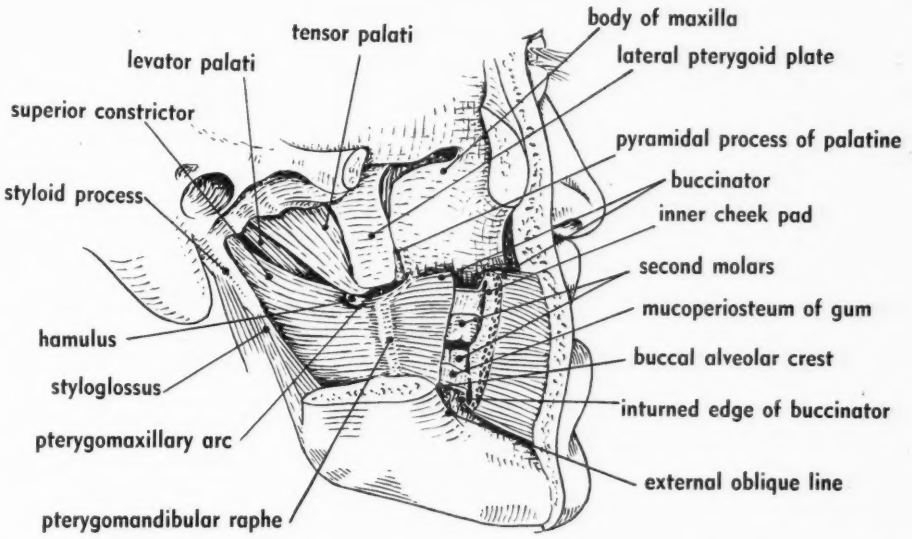

Fig. 12.—The buccinator muscle in oblique posterolateral view to show its relation to the jaws and inner cheek pad.

molar fossa which receives a part of the buccal pad of fat (see Fig. 7). The temporal crest, on which the deep tendon of the temporalis muscle is inserted, ends below in the rough retromolar triangle over which lies the retromolar pad. The borders of the triangle continue forward into the buccal and lingual alveolar crests.

The mylohyoid line marks the attachment of the tendinous part of the mylohyoid muscle and it ends abruptly on the lingual tuberosity below and behind the last molar tooth. The fleshy part makes no mark on the bone. The groove for the nerve to the mylohyoid muscle lies below and parallel to the line and is usually taken as the upper boundary of the area for the attachment of the medial pterygoid muscle, but, as we have found the nerve commonly enclosed within the muscle fibers (see Fig. 8), we have shown the insertion as more extensive.

DISCUSSION

The dissections illustrated were made in Baghdad, but through the kindness of Professor Ruth Bowden of the Royal Free Hospital, London, we have been able to confirm most of the points we have mentioned in a European subject, and there is no reason to expect any considerable racial differences in the region. Also, through the kindness of Mr. I. R. H. Kramer, Mr. John Lee, and Mr. R. I. Nairn, of the

Eastman Dental Hospital, we have been able to confirm several points, particularly the attachments of the buccinator muscle, in microscopic preparations. A few special topics may be mentioned.

The retromolar pad (Figs. 1 and 8) is particularly well developed in the specimen from which Fig. 1 was drawn. Being formed by an extension from the main mass of palatal glands, the retromolar pad may have no particular function. Possibly, being soft and extensible and being placed in line with and behind the molar teeth, it may serve to fill the gap behind them and prevent the accumulation of food there when the mandible is depressed.

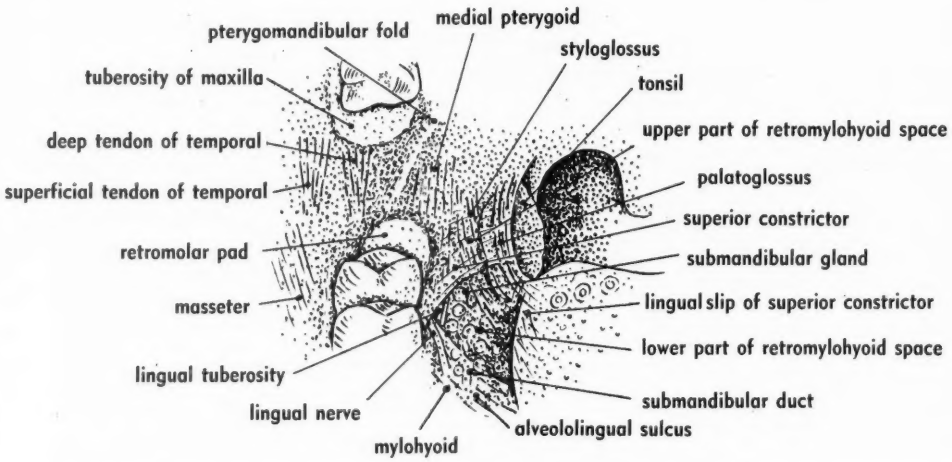

Fig. 13.—Diagram of the structures in the mandibular molar region based on observations on the living mouth and on dissections.

The retromylohyoid space, which covers the area between the posterior border of the mylohyoid and the palatoglossus muscles, falls naturally into two parts. The posterosuperior portion overlies the superior constrictor muscle which, with the mucous membrane covering it, forms the retromylohyoid curtain described by Edwards and Boucher.[1] The anteroinferior portion overlies a triangular area, bounded by the posterior border of the mylohyoid muscle, the lower border of the superior constrictor muscle, and the tongue (Fig. 13). This area forms a part of the buccopharyngeal gap which Mohiuddin and Martin[4] have defined as "bounded above by the lower border of the superior constrictor muscle, below by the upper border of the middle constrictor muscle and in front by the posterior border of the mylohyoid muscle." Through this part of the gap pass the lingual nerve, the deep part of the submandibular gland and its duct, and the styloglossus muscle. These structures, together with parts of the lingual tuberosity of the mandible, the medial pterygoid muscle, the tonsil, and a lingual slip of the superior constrictor muscle, lie under this portion of the retromylohyoid space.

The lingual nerve is commonly said to groove the mandible, the groove being placed inferiorly to the lingual tuberosity. The nerve can, in fact, be pressed against the bone in this position and may be palpable from the mouth in this part of its

course. But, as shown in a section through the tuberosity (Fig. 9), the nerve is here separated from the bone by the thickness of the mylohyoid muscle. More posteriorly the nerve is directly related to the mandibular ramus (Figs. 7 and 8), but there the nerve is covered by the medial pterygoid and superior constrictor muscles.

The inner cheek pad (Figs. 8, 9, and 12) appears after formalin fixation as a homogeneous mass of dense tissue filling the space between the oral epithelium and the inner surface of the buccinator muscle. Mr. Nairn's sections, however, and others prepared by Professor A. Mohiuddin of Baghdad, show that, in fact, over most of the area a chorion can be distinguished from a fibrofatty layer. No perimysium can be found on the inner surface of the buccinator muscle, which is rough with isolated bundles of muscle fibers passing away from the main mass into the fatty tissue. The pad as a whole allows the inner surface of the cheek to be pressed against and between the teeth, filling up any deficiencies. On the outer surface of the muscle, a perimysium separates the muscle fibers from the buccal pad of fat.

The incurving of the fibers of the buccinator muscle at its attachments to the jaws has been little stressed in the literature, but is quite clear in both macroscopic and microscopic sections. The attachments are placed on the bone between the crown and the root apices. The level corresponds approximately to the line of union of the mucoperiosteum and the free mucous membrane, but a precise description must await further microscopic work.

It is extraordinary that the soft extensible pterygomandibular raphe (Figs. 3 and 12) should have been considered a palpable structure. Possibly its designation as a ligament is responsible for this error, for a ligament formed of longitudinally arranged inextensible fibers would become taut and palpable as the mouth was opened. The raphe lies over the anterior border of the medial pterygoid muscle (Fig. 7), and it is this massive structure that forms the large soft prominence usually ascribed to the raphe.

SUMMARY

1. The structure of the lower molar region of the mouth has been studied in anatomic preparations and in the living subject.
2. The retromolar pad contains an extension of the palatine salivary glands and lies over the retromolar triangle of the mandible, overlapping the attachments of the pterygomandibular raphe, the buccinator and superior constrictor muscles, and the lingual tuberosity.
3. The pterygomandibular raphe is not palpable in the living mouth; but the masseter muscle when it is tensed, the superficial and deep tendons of the temporalis muscle, and the anterior border of the medial pterygoid muscle when it is stretched can all be distinguished.
4. The muscle band described by Fish[7] from the work of Garmany, crossing from the mandible to the tongue behind the alveololingual sulcus, was not found.
5. The margins of the buccinator muscle attached to the maxilla and mandible are turned in so as to arise nearer the tooth crowns than is commonly believed. The inner cheek pad of soft but dense connective tissue covers the inner surface of the muscle.

Our thanks are due to the many colleagues with whom we have discussed our findings, and particularly to the staffs of the Eastman Dental Hospital and the Royal Free Hospital, and to Mr. R. Sprinz of Sheffield, England.

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THE TORI AND MASTICATORY STRESS

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THE TORUS PALATINUS is a bony prominence or development within the median line area of the palate. The torus mandibularis is a bony prominence found usually within the first mandibular cuspid and the first molar area. One or more tori may be present. The tori are composed of cancellous bone covered by compact bone which may be laminated. The opinion has been expressed that the torus is caused by misplaced embryonic cells; however, most textbooks state that the cause is unknown. I have observed the torus mandibularis disappear over a period of 5 to 7 months after extraction of teeth and resection of the alveolar process. This is not, however, a constant prognosis.

ENAMEL STRUCTURE

The enamel of the teeth appears shiny and flintlike. The teeth are formed well and have the appearance of sturdiness. The cusps are well interdigitated. The teeth distal to an edentulous space are impeded in migration anteriorly because of the dense alveolar process.

FACIAL FEATURES

The face has well-developed features with a strongly developed mandible. I have never observed a torus formation in a person with a Class II profile (receding chin).

FACTORS PREDISPOSING TO TORUS DEVELOPMENT

There must be an abundant supply of calcium present systemically for torus development. The alveolar process is made up of a uniform and dense trabecular structure. In some individuals the intertrabecular space indicates the calcium content. If recession of the alveolar ridge has occurred, it will be uniform except in localized areas where there are mechanical irritants. The increase in calcium deposits decreases or eliminates the dissipation of the force of closure.

MASTICATORY MUSCLE STRESS

The occlusal plane develops at a right angle to the resultant force of muscle stress. The stress zone is the region of the premolars and molars (Wilson's parallelogram of forces). During a functional closure, however, the stress is at a right

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*Author deceased.

angle to the mandibular occlusal plane until occlusion of the teeth occurs. The stress upon the maxillary teeth is at an acute angle and, therefore, directed anteriorly until occlusion of the teeth occurs.

THE DISSIPATION OF MASTICATORY STRESS

The resultant force of a masticatory closure is at a right angle to the long axis of the teeth. The power utilized in the process of mastication is dissipated by the periodontal tissues, the trabecular structure of the alveolar process, and the walls of the sinuses. If the axial lines of the teeth were extended they would meet at a common center, which is called the stress center or the alba center. The force of mastication is completely dissipated at this center. This resilience or cushioning of force is Nature's method of conserving periodontal health. Although the cusp inclines come into contact upon occlusion, and although the maxillary posterior teeth incline buccally and the mandibular posterior teeth incline lingually, the force of occlusion is neutralized so that the resultant force is at a right angle to the axial lines of the teeth.

ABRASION OF TEETH AND THE TRANSFER OF MASTICATORY STRESS

The predisposing factors plus the abrasion of teeth cause a decrease in vertical dimension of occlusion. The distance between the mandibular first molar teeth is greater than the distance between the bicuspids because of the narrowing of the dental arch anteriorly. As the vertical dimension of occlusion decreases, the lingual cusps of the maxillary posterior teeth and the buccal cusps of the mandibular posterior teeth interlock more securely. Abrasion continues in some mouths until the mandibular buccal cusps and the maxillary lingual cusps are completely obliterated. For each square millimeter of increased flat tooth surface, four times as much power is required to masticate food. The vertical overlap of the anterior teeth also increases as the vertical dimension of occlusion decreases.

These factors alter the normal dissipation and direction of force upon the teeth. The closure causes shock, and the thrust is increased anteriorly as the vertical dimension decreases. The formation of mandibular tori is caused by the shock of force upon the abraded cusps and by the right angle transmission of the force from the buccal surface of the posterior teeth to some point on the lingual surface of the mandibular alveolar process. Nature aids in reinforcement.

The torus crest will be directly in a line from first molar to first molar when there is a full complement of teeth and the predisposing factors are present without abrasion. The extraction of the posterior molar teeth in these mouths will change the direction of force, and a torus will develop more anteriorly. Two or more tori may be present in the palatal vault.

TORUS PALATINUS

The excementosed periodontal tissues and the alveolar process become a medium of transmission of the masticatory force. This is not a normal dissipation of the force. The hard palate, because of its density, structure, and form, becomes a

medium of dissipation of the abnormal direction of force in the median line area via the alveolar process and maxillae. The abnormal direction of force acts as a "pathologic shock." This pathologic shock is a stimulant which causes Nature to come to the rescue with additional calcium and cancellous structure.

CONCLUSION

Tori are the result of Nature's defense, to protect the oral cavity from the abnormal dissipation of masticatory stress.

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TROUBLE SHOOTING IN COMPLETE DENTURE PROSTHESIS*
Part I. Oral Mucosa and Border Extension

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THE SUCCESSFUL SOLUTION of difficult diagnostic problems depends on powers of observation, artistic skill, and scientific preparation. For scientific therapy, knowledge of the disease is a prerequisite. Such knowledge is based on an understanding of the etiology. The treatment of a disease by utilization of a knowledge of its etiology and an understanding of the action of the therapeutic agents is called the etiological mode of procedure.[1]

The empirical mode of procedure is one which may effect cures or improvements of symptoms even though there is no knowledge or understanding of why and how such results are obtained. For instance, relieving a denture at the wrong spot may cause the denture to lose its basal seat support, where it is needed most. Thus, if the sore spot is on the crest of the ridge in the first lower molar region, relief under the second molar will cause new trouble. Pressure on a food morsel between the upper and lower second molars will displace the denture upward in the region of the incisors. Such a mishap may suffice to render the denture a failure.

Greater experience and more training are required to accomplish both proper relief of pain from dentures and denture correction than are required for the initial construction. This means that the dentist must be a diligent student. The surface form and structure of the mucosa, its consistency, color, looseness and turgescence, degree of keratinization or cornification, and its many other physiologic attributes should be studied carefully. Such knowledge is indispensable in differential diagnosis between normal and abnormal and between physiologic and pathologic phenomena.[2]

TYPES OF ORAL MUCOSA

The oral mucosa may be classified into three distinct types: (1) the masticatory mucosa, (2) the specialized mucosa, and (3) the lining mucosa.

Masticatory Mucosa.—The masticatory mucosa covers both alveolar ridges and is attached directly and rigidly to the periosteum of the underlying bony structures. It is the portion of the mucosa that endures pressure and friction during mastication as food slides onto the buccal and lingual mucosa of the alveolar ridges. Some periodontists attribute therapeutic value to this friction, because the massaging of the mucosa stimulates blood circulation.

*This is the first of a series of articles on this subject.

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The masticatory mucosa also covers the palatal vault. Here, too, the mucosa is attached directly and rigidly to the periosteum of the underlying bone by means of dense bands of fibrous connective tissue (Fig. 1). During mastication, food is thrown and held firmly against the palatal vault. Consequently, the mucosa of the palatal vault bears the stress of mastication in a manner similar to that of the alveolar mucosa.

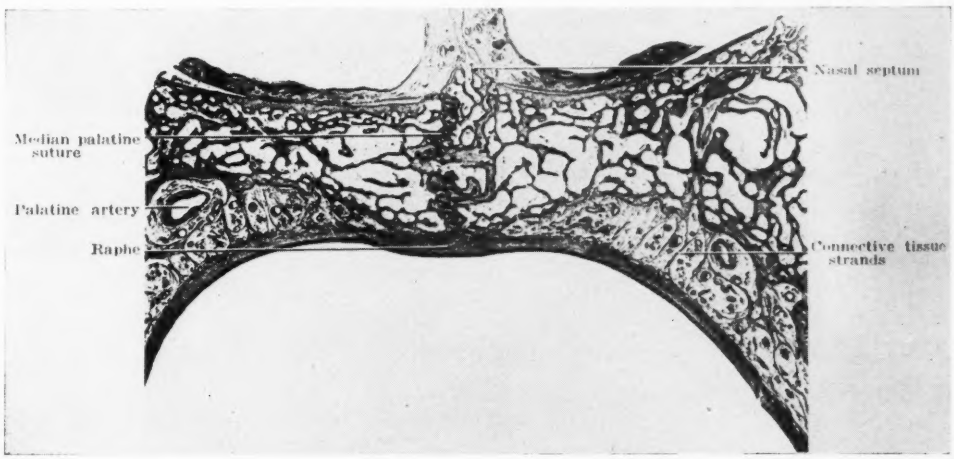


Fig. 1.—Transverse section through hard palate. An intimate relationship exists between the mucous membrane and the periosteum in the masticatory mucosa of the hard palate. A knowledge of this relationship is necessary to understand the function of the basal seat of dentures. (From Pendleton, E. C.: The Minute Anatomy of the Denture Bearing Area, J.A.D.A. 21:488, 1934.)

The masticatory mucosa must, therefore, be qualified to resist the frictional impact of hard food substances during mastication. Nature seems to have given additional protective qualities to the masticatory mucosa in its superficial and deepest layers. The upper layer of the stratified squamous epithelium that covers this mucosa is highly keratinized, and the lowest layer is attached firmly and rigidly to the periosteum. The high degree of physiologic keratinization imparts greater resistance to pressures of various kinds and magnitudes, while the firm attachment is also a protective device. Were this mucosa attached loosely (as occurs in certain pathologic conditions), it would be susceptible to injury resulting from friction against the underlying bone during mastication.

The masticatory mucosa can be divided further into *noncushioned* and *cushioned* categories according to the presence or absence of a submucous layer. In contrast to the mucosa that covers the hard palate, the submucous layer of the alveolar mucosa cannot be recognized distinctly. The dense and nonelastic connective tissue of the lamina propria penetrates and fuses with the periosteum of the alveolar process. The hard palate, on the other hand, except for the palatine raphe, has a distinct submucous layer. The latter is divided into irregular compartments containing adipose tissue anteriorly and mucous glands posteriorly (Fig. 2). "The presence of fat or glands in the submucous layer acts as a hydraulic cushion comparable to that

which we find in the subcutaneous tissue of the palm of the hand and the sole of the foot. The presence or absence of a distinct submucous layer permits the subdivision of the masticatory oral mucosa into the non-cushioned and cushioned zones." (Fig. 3.) "The non-cushioned zone consists of the gingiva and the palatine raphe, the cushioned zone consists of the remainder of the mucosa covering the hard palate."[2]

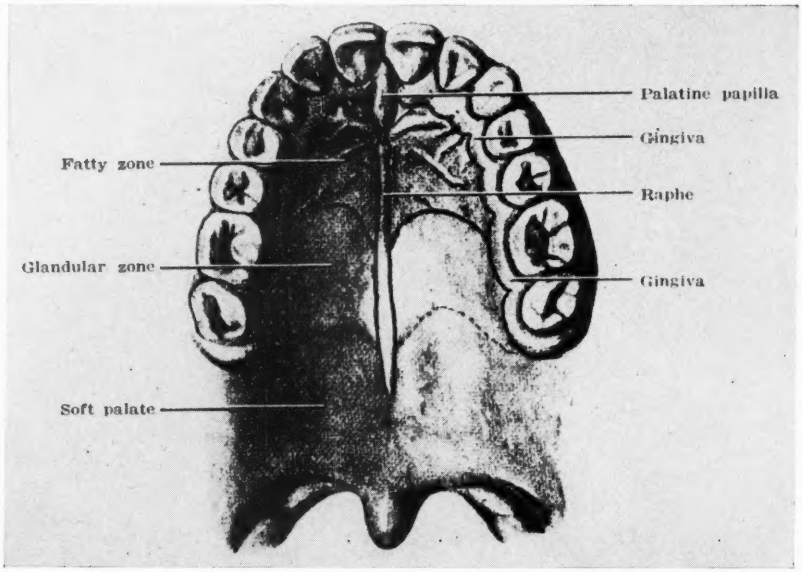


Fig. 2.—Surface view of hard and soft palate. The anteroposterior distribution of the fatty and glandular zones provides a cushionlike seating surface for the upper denture. (From Orban, B.: Oral Histology and Embryology, ed. 4, St. Louis, 1957, The C. V. Mosby Co.)

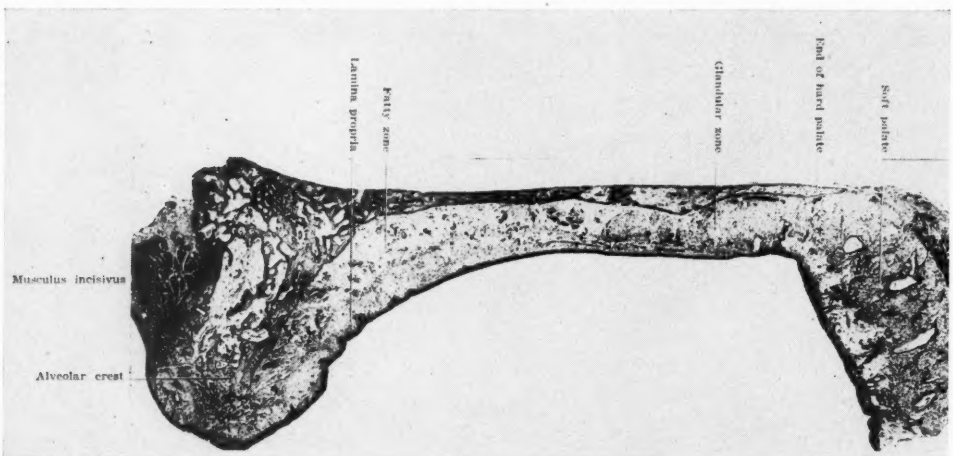


Fig. 3.—Longitudinal section through hard and soft palate lateral to midline. The disposition of the fatty and glandular zones affects the stability and retention of the upper denture. Too much or too little fatty and glandular tissue is unfavorable to denture stability and proper function. An average amount of these tissues and their proper distribution are conducive to the best results. (From Orban, B.: Oral Histology and Embryology, ed. 4, St. Louis, 1957, The C. V. Mosby Co.)

Specialized Mucosa.—The specialized mucosa covers the dorsal surface of the tongue, which is a highly specialized organ, hence the designation "specialized."

The dorsal surface of the tongue is rough and irregular and is second highest in the degree of cornification of its epithelial covering (Fig. 4). A V-shaped line is situated between the anterior two-thirds of the tongue (the body) and the posterior third (the base). A great number of specialized papillae can be observed on the upper surface of the tongue. They are, from the front backward:

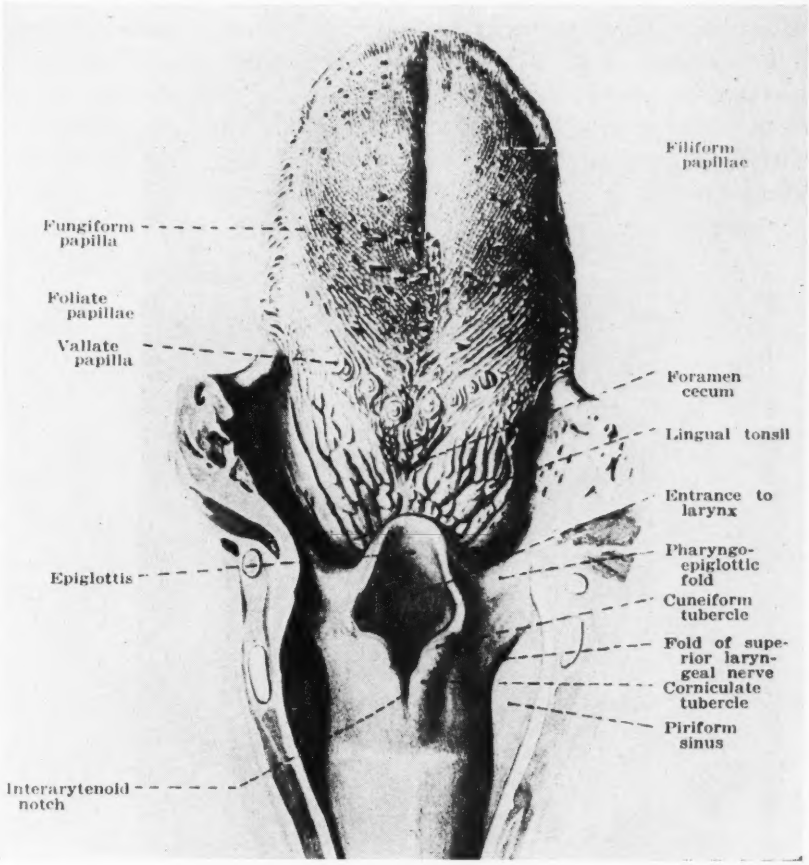


Fig. 4.—Surface view of human tongue. The mucous membrane of the dorsum of the tongue is highly specialized. (From Sicher, H.: Oral Anatomy, ed. 2, St. Louis, 1952, The C. V. Mosby Co.)

Filiform (thread-shaped) papillae: These projections are a connective tissue core which carries secondary papillae.

Fungiform (mushroom-shaped) papillae: Scattered between the filiform papillae are the fungiform papillae, which are reddish, round prominences rich in blood supply. They can be observed through the relatively thin epithelium. Some of the fungiform papillae contain taste buds.

Circumvallate (walled-in) papillae: These papillae make up the dividing line between the body and base of the tongue. At the apex of the V-shaped triangle of

the tongue is situated the foramen caecum linguae, which is the remnant of the thyroglossal duct. Behind the circumvallate papillae the tongue is studded with round or oval prominences known as the lingual follicles. A number of lingual follicles taken together are called the lingual tonsil.

Lining Mucosa.—The outstanding characteristics of the lining mucosa are that its epithelium is thin and lightly or not at all hornified and that the lamina propria is very thin. The lining mucosas in various zones of the oral cavity can be differentiated from one another by the characteristics of their submucosa. When the lining mucosa covers muscles such as the buccinator on the cheeks or the orbicularis oris on the lips, the mucosa is immovably attached to the fascia of the muscle (Fig. 5); however, the mucosa is usually highly elastic in these regions. In some instances, the lining mucosa lacks the submucous layer altogether, as occurs on the undersurface of the tongue (Fig. 6). In other zones, such as the fornix vestibularis, the submucosa is loose, of considerable volume, and attached movably to the deep underlying structures. These characteristics of the lining mucosa safeguard it from

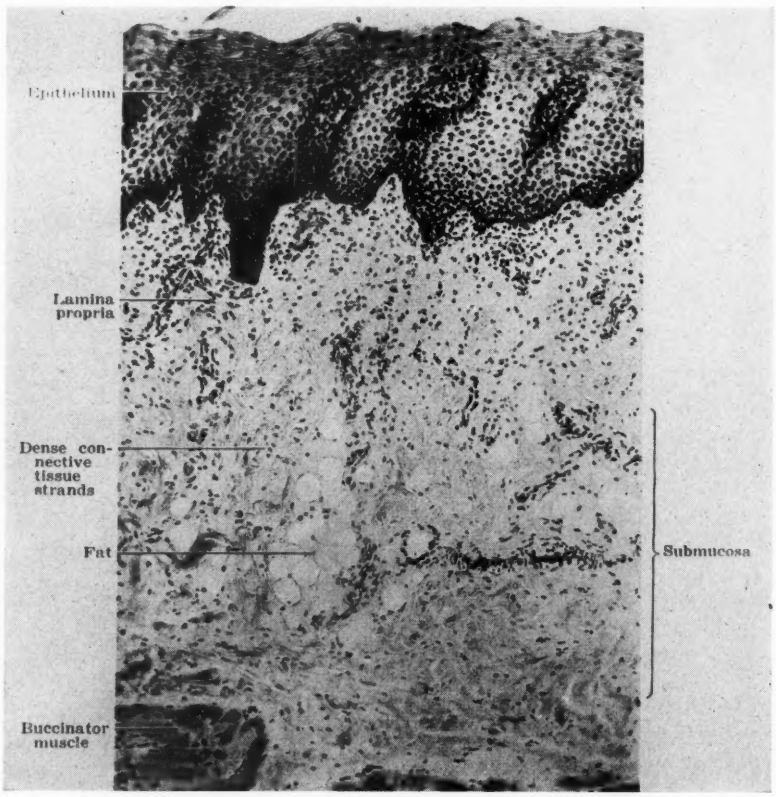
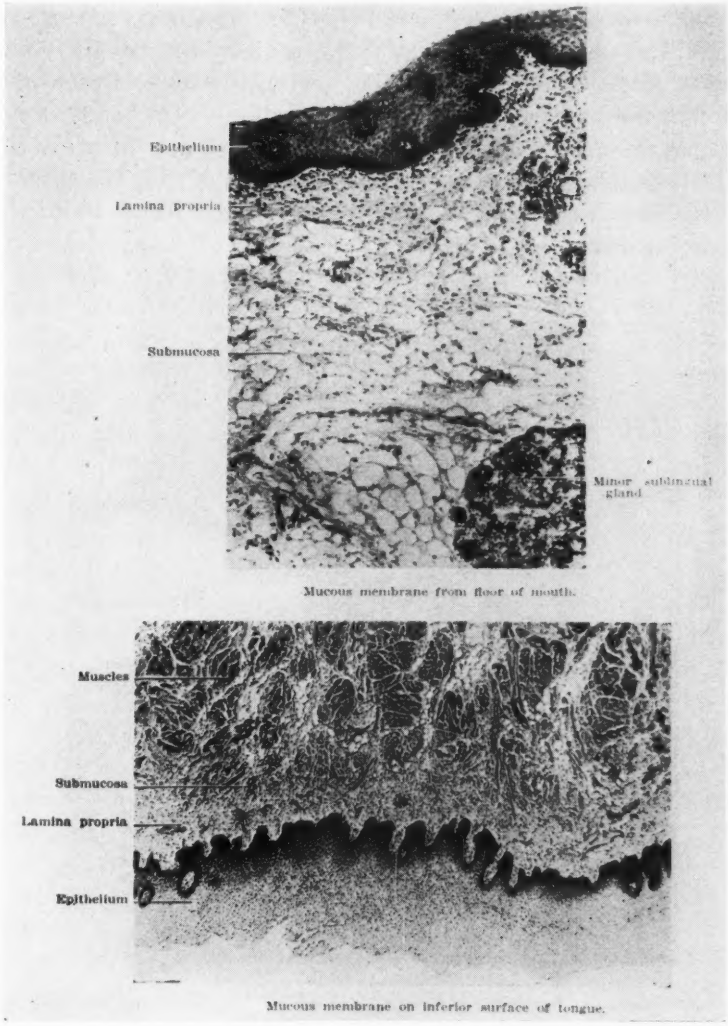


Fig. 5.—Section through mucous membrane of cheek. An interrelationship exists between the lining buccal mucosa and the buccinator muscle, which explains why the mucosa lining the cheek is not usually caught between the occlusal surfaces of the upper and lower teeth. This fact also explains why patients become more susceptible to cheek biting with the advance of old age and the loss of the turgescence of the oral mucosa. (From Orban, B.: Oral Histology and Embryology, ed. 4, St. Louis, 1957, The C. V. Mosby Co.)

A.



B.

Fig. 6.—*A*, The mucosa of the floor of the mouth is lightly keratinized, whereas, *B*, the mucosa on the undersurface of the tongue is completely devoid of keratinization. (From Orban, B.: Oral Histology and Embryology, ed. 4, St. Louis, 1957, The C. V. Mosby Co.)

being injured by the various movements of the muscles to which it is attached. Too, these qualities prevent the formation of mucosal folds and wrinkles that might be caught between the teeth during mastication. With the approach of old age and the concomitant lack of elasticity and turgescence of the mucosa, however, susceptibility to tongue and cheek biting increases.[2]

PATHOLOGIC CONDITIONS INDUCED BY DENTURES

Each type of mucosa in its respective location reacts differently to injury by dentures and each manifests a distinct type of ulceration, irritation, and vascularize-

tion. Accordingly, acute and chronic soreness of the oral mucosa caused by dentures may be divided according to location into four types: (1) those situated in the lining mucosa and caused by overextension of denture borders, (2) those situated on the masticatory mucosa and caused by traumatic occlusion of various types, (3) those situated on the specialized mucosa and caused by tongue biting or by friction of the dorsal surface of the tongue against the occlusal surfaces of the artificial teeth or against the lingual surface of the palate of the upper denture, and (4) those situated on the undersurface of the masticatory mucosa and caused by friction of the mucosa against the underlying bone.

Fig. 7.—The lesions in the lining mucosa caused by overextended denture borders are indicated by the arrows. (From Landa, J. S.: Practical Full Denture Prosthesis, ed. 2, Brooklyn, 1954, Dental Items of Interest Publishing Co.)

ACUTE TRAUMATIC LESIONS IN THE LINING MUCOSA CAUSED BY OVEREXTENDED DENTURE BORDERS

These lesions are usually slitlike fissures in the lining mucosa, varying in length and depth according to the particular zone and extent of denture overextension (Fig. 7). The largest fissure-type ulcerations observed are those caused by overextension of the distolingual border of the lower denture in the area of the retromolar pad. Severe damage to the oral mucosa is not caused alone by the amount of overextension of the denture border, but perhaps more by the degree of mobility of the tissue in function against the overextended border. The curtain connecting the soft palate with the tongue and tissues of the floor of the mouth is highly mobile. It

is formed medially by the palatoglossus muscles, laterally by the pterygomandibular raphe, and between these by the mylohyoid muscle. This curtain moves with all movements of the tongue and muscles of the floor of the mouth. The retromylohyoid curtain, fibers of the buccinator muscle, the pterygomandibular raphe, and the mucosa of the floor of the mouth in the first and second molar region are particularly vulnerable to denture overextension. In severe acute conditions the fissure sloughs at its periphery and is intensely red at the base. The lining mucosa of the floor of the mouth is sensitive to all kinds of irritation because it is poorly kertanized or altogether nonkeratinized under the tongue.

The interrelationship and manner of transition of the various types of mucous membranes are such that there is no abrupt transition or definite line of demarcation. The various types of mucous membranes merge with one another gradually, and there is usually a neutral zone 2 to 3 mm. wide between them. This zone, belonging to neither of the two areas it joins, possesses the characteristics of both. Thus, the neutral zone situated between the masticatory and lining mucosa is not as highly keratinized as the masticatory mucosa, but is more keratinized than the lining mucosa. It is not as immovable as the masticatory mucosa, nor is it as movable and elastic as the lining mucosa. It cannot withstand pressure as well as the masticatory mucosa, but it is not as vulnerable to pressure as the pure lining mucosa. Denture borders should therefore extend to cover this neutral zone, but no farther. This strip of mucosa is movable and soft only to the extent that it can adapt and mold itself against the denture borders and impart a border seal. It is not so resistant and elastic that it would tend to displace the denture. Our decisions on how far to extend the borders of dentures, or on how far to reduce them when they are over extended, are based on such knowledge.

The postpalatal seal area is also a meeting place of the masticatory and lining mucosas. The neutral zone in this area may be extremely narrow, and it may be desirable to extend the denture border onto the pure lining mucosa for adequate retention. As a rule, however, the postpalatal seal should displace only the neutral zone between the hard and soft palate, because this strip of tissue is the only one that may be safely displaced and even here only within certain limitations. Overextension, beyond the point of tolerance either horizontally or in depth, will cause a slitlike or irregular, pressured ulceration.

ADJUSTMENT OF DENTURES FOR BORDER OVEREXTENSION

Border reduction that is excessive because of the anxiety to provide relief from pain should be guarded against in denture adjustment, lest irreparable damage to the denture result. Underextension is an evil, not mitigated by the fact that the pain is gone at once. If a convex area of the denture border causes a 1 cm. long ulceration, the dentist should not reduce the border of the denture by that same amount. In reality, the original irritation is probably caused by the most convex, middle 3 mm. of the border (Fig. 8). Accordingly, the length of the denture border to be reduced should be 3 mm. and not the full length of 1 cm. The depth of relief should be as shallow as possible. Frequently 0.5 mm. of relief in depth is adequate if it is followed by a thorough polishing. The patient need not become completely

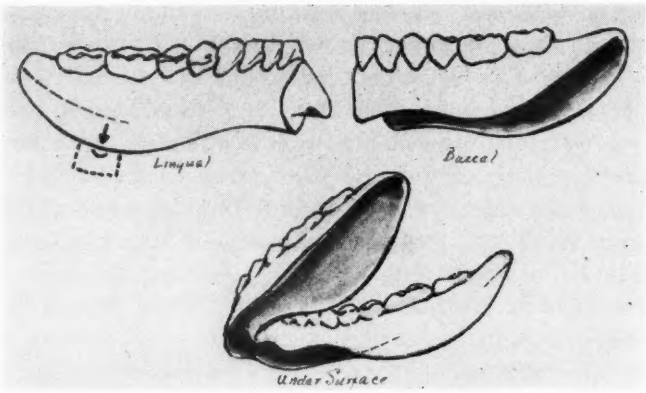


Fig. 8.—In instances of tissue irritation from overextension, only the most pronounced convex portion of the denture border should at first be reduced. Hasty relieving of the entire border which manifests vascularization may lead to excessive underextension (arrow). (From Landa, J. S.: Practical Full Denture Prosthesis, ed. 2, Brooklyn, 1954, Dental Items of Interest Publishing Co.)

Fig. 9.—The arrows indicate several types of tissue irritation and ulceration: *1*, a slitlike ulceration just posterior to the junction of the hard and soft palate, *2*, a slitlike ulceration in the lining mucosa lingual to the retromolar pad, *3*, a small, round ulceration in the masticatory mucosa, *4*, a longitudinal ulceration on the undersurface of the mucosa caused by a sharp mylohyoid ridge, and *5*, an oval ulceration on the masticatory mucosa. (From Landa, J. S.: Practical Full Denture Prosthesis, ed. 2, Brooklyn, 1954, Dental Items of Interest Publishing Co.)

pain free while still in the dental chair; it is sufficient for him to state that the pain has been eased considerably. Within 1 to 3 days the ulcerated tissue should return to normal if the border has been adjusted properly.

Two fissurelike ulcerations in the adjacent lining mucosa can be observed in instances of considerable overextension of the extreme distal end of the lingual border of the lower denture. These ulcerations are probably caused by tongue movements to the right and left side, and are usually found close and parallel or concentric to each other. Reduction of overextension of the lower border of the lingual flange of the lower denture in the molar region should be such that the border remains 2 mm. below the mylohyoid ridge. An ulcerated fissure in the region of the genioglossus muscle frequently caused by denture border overextension may not be due so much to border overextension in length as to displacement of the mucosa by this border at its inner or tissue surface. A rounding out (not shortening) of the border at its tissue surface frequently permits the tissues to return to normal. If a certain irritated spot is suspected upon visual examination, a digital examination should follow for verification. A light contact of the index finger with the suspicious spot should elicit a quiver of the patient's facial muscles. (Fig. 9.)

Once it is established that the irritation has been caused by denture overextension, a definite procedure is indicated. The denture spot corresponding to the irritation in the mouth is determined by careful examination of the denture and is marked on the denture border with an indelible pencil. The oral mucosa of the affected area is dried and the denture is replaced quickly with pressure. The dentist places the fingers of his left hand under the patient's tongue when removing the denture to avoid the pencil mark smudged at or near the irritation. The operation is repeated until the pencil mark falls upon the middle of the irritated area and then the denture border is reduced judiciously and polished highly. The same procedure is used for the buccal and labial borders of the maxillary and mandibular dentures.

Adjustment of dentures is a very important step in denture service. It is work of precision and requires keen judgment and digital dexterity in its performance.

SUMMARY

The oral mucosa was described histologically and classified according to function. Pathologic conditions induced by dentures were discussed. The method of adjustment of dentures was outlined and its importance emphasized.

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FIXED PARTIAL DENTURES

TREATMENT PLANNING FOR OCCLUSAL REHABILITATION

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OCCLUSAL REHABILITATION is the general practice of biologic dentistry. This practice consists of those procedures which produce a state of oral health capable of perpetuation under functional stress.

A treatment plan will be successful only after a complete diagnosis is established. A procedure that integrates diagnosis with treatment will be discussed.

DIAGNOSIS

An oral examination, a complete series of roentgenograms including bite-wings, study casts, and a medical history which includes an evaluation of psychogenic factors are indispensable aids for a competent diagnosis.

Meticulous scrutiny of the oral tissues is of special importance. Aberrant manifestations such as scarring, fistulas, or neoplasms, and deviations from normal gingival form, color, and pocket depth are important findings. Conditions of restorations, caries susceptibility, occlusal abnormalities, tooth malposition, and mobility are noted. All teeth are tested for vitality, and the results are recorded for future reference.

Study casts are mounted in centric relation on an adjustable articulator to determine the maxillomandibular relationships. Pathologic interferences, especially those on the balancing side, are more discernible than by oral examination. Matching of pathologic wear facets is attempted.[1]

Roentgenograms help in recognizing pathologic conditions which must be removed or restored to a state of health capable of supporting normal function. The conditions of the crowns, roots, and pulp of the teeth, the periodontal membrane, the lamina dura, and investing bone can be studied in greater detail.

With a thorough medical history available, many unfortunate situations can be prevented. The history includes the patient's age, occupation, and drug intake; infomation concerning cardiovascular diseases, organic or endocrine dysfunction,

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and pain in or around the face, head, and neck; and a history of neurosis or psychosis. Some information is obtained best through consultation with the patient's physician.

An evaluation of tensional and occupational habits[2] is made and brought to the patient's attention. This may halt such a habit or pave the way for successful biomechanical treatment.

INITIAL PERIODONTAL THERAPY

Initial periodontal therapy is of a marginal nature and consists of a thorough scaling and/or curettage. This therapy is an important procedure for four reasons:

1. The results may show that no further periodontal therapy is necessary, especially when local irritants have caused a hyperplastic response.
2. The results may show that surgical and equilibrative procedures are necessary to fully eradicate any residual periodontal involvement.
3. The dentist may exercise his judgment about the healing capacity of the patient.
4. The removal of teeth is accomplished in a field débrided of local irritants. Postoperative healing is accelerated in this environment.

SURGERY

The attempt to retain teeth which are hopelessly involved periodontically or endodontically may prove unsuccessful and possibly result in attachment loss of adjacent teeth. Such involved teeth should be extracted.

Malaligned teeth, unless they are key teeth by virtue of their location and attachment support, should be removed. Impacted teeth, especially those which show oral penetration and poor axial inclination or a lamina dura, should be removed also.

PRELIMINARY OCCLUSAL EQUILIBRATION

When no signs of occlusal trauma are discernible roentgenographically, no intervention is necessary, irrespective of the existing jaw relationships. If such signs are present, however, occlusal equilibration is necessary (Fig. 1). The maintenance of a negative occlusal sense is an important consideration during equilibrative procedures.

In most mouths undergoing occlusal rehabilitation, many teeth show a fair degree of periodontal breakdown. The first step in occlusal equilibration is the judicious narrowing of the posterior teeth in a buccolingual direction. This decreases the range of functional lateral contacts and often reduces buccolingual stresses to within physiologic limits. Stress reduction is important especially when mobile teeth are being treated.

The correction of the occlusal plane involves the elimination of gross disharmonies. Alteration of uneven marginal ridges, plunger-type cusps, and extruded and malpositioned teeth will reduce many traumatic interferences and allow smoother mandibular pathways.

Production of a favorable crown-to-root ratio is possible particularly on anterior teeth. The degree of necessity is directly proportional to tooth mobility or other traumatic symptoms. The limits of grinding are esthetics and disocclusion in all but one of the functional positions and excursions.

Some dentists believe that the only tooth contact of any significance occurs during centric occlusion and that balance in eccentric positions is not necessary.[3,4] No one, however, will question the importance of centric relation and centric occlusion. That both coincide is of paramount importance (Figs. 2, 3, and 4). The possibility of generating traumatic forces as a result of centric relation deflective occlusal contacts is generally accepted.

Fig. 1.—The typical "hour glass" lesion in the periodontal membrane and supporting bone around the first bicuspid is due to occlusal traumatic forces.

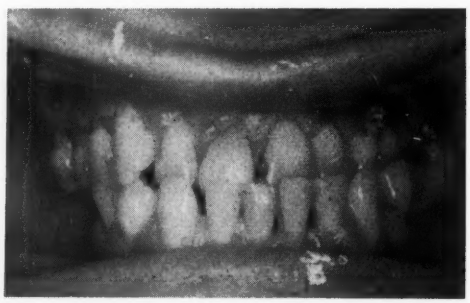


Fig. 2—The teeth are contacting in centric occlusion.

OPERATIVE PROCEDURES

Caries must be eradicated meticulously with restorations that incorporate biologic principles.[5] Overbuilding occlusal surfaces may result in a convenience position with possible damage to the attachment apparatus of involved teeth.[6] Insufficient tooth replacement may cause the identical sequelae as a result of the loss of centric occlusion holding points and possible interference in balancing side contacts due to cusp migrations. Disease and dysfunction of the temporomandibular joint are often encountered.[7,8]

ENDODONTIC TREATMENT

Epstein[9] defines endodontics as "that brand of dental science devoted to the conservation of teeth by surgical and therapeutic means as required by the conditions of their pulps and associated tissues." The proved techniques of pulpotomy,[10]

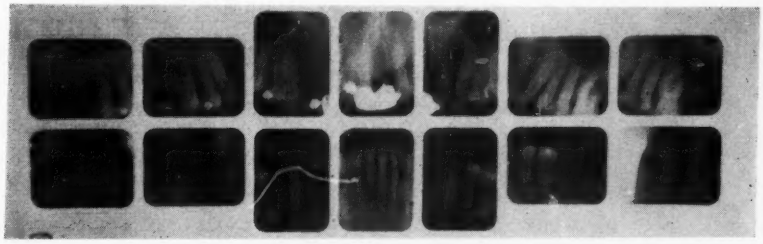


Fig. 3.—Enormous traumatic lesions are present, especially around the lower left central and the upper right central incisors. The lower left central incisor has a mobility of 4 plus.

Fig. 4.—As a result of multiple extractions and loss of the normal dental arch relationship, the first contact in centric relation is the lower left incisor. The next contact is the upper left lateral incisor, until the convenience position is reached.

Fig. 5.

Fig. 6.

Fig. 5.—The distobuccal root of a second molar with much of its investing bone gone had no attached gingivae on the root.

Fig. 6.—Although there was no trifurcation involvement, amputation of the root was performed (after endodontic therapy) rather than mucogingival surgery in an attempt to obtain a gingival attachment.

pulpectomy, apical curettage, and root resection[11,12] conserve teeth whose treatment is based on a concise diagnosis. After periapical healing, the continuity of the periodontal membrane is assured.[13] These teeth may be used without apprehension as abutments for any rehabilitative procedure.

Occasionally it is necessary to treat a healthy vital tooth endodontically because of poor alignment, insufficient crown bulk for retention, or loss of the attachment on one or more roots (molars) (Figs. 5, 6, and 7).

Fig. 7.—A temporary acrylic resin fixed partial denture was constructed immediately after operation. The molar was treated anatomically as a bicuspid. After healing, further periodontal therapy was instituted prior to the construction of the permanent fixed partial denture.

TEMPORARY SPLINTING

Temporary splinting is an important adjunct to some forms of orthodontic and periodontic therapy during the rehabilitative procedure. (Fig. 8). In the former, a more conducive environment is produced for the reorganization and stabilization of the surrounding bone around moved teeth. Migration of moved teeth is prevented. In the latter, the splint provides the necessary rigidity, especially for mobile teeth, to maintain the organizing blood clot intact for optimum healing after surgery. Furthermore, occlusal stresses are shared with healthier teeth, and an environment for the resolution of traumatic lesions is established.

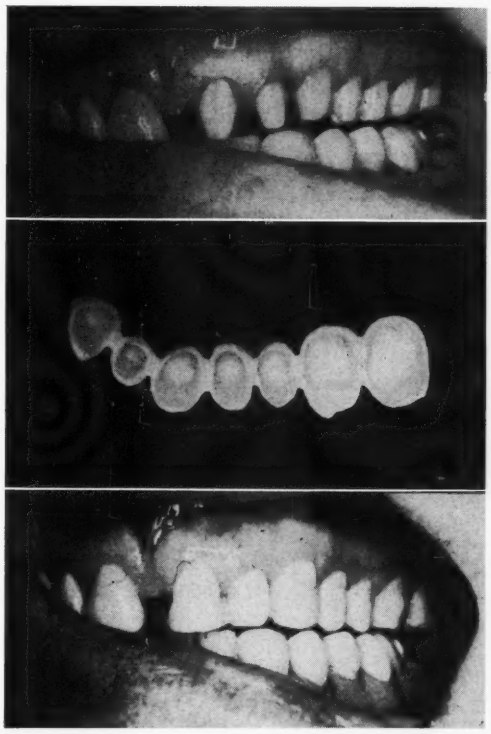
Many methods of splinting are available.[14,15,16] Good results may be obtained for anterior teeth with wire and acrylic resin. The resin is painted on the wire to fix it, thus stabilizing the involved segment. Soldered orthodontic bands or acrylic resin-fixed splinting is best for posterior teeth. When permanent splinting is deemed a necessity, the resin splint is preferable. Biologic principles of form must be incorporated in splint construction; otherwise treated marginal tissues may break down.

FURTHER PERIODONTAL THERAPY

Periodontal therapy should attain two objectives. The first is the eradication of pathologic lesions occurring in the marginal gingivae and attachment apparatus of the teeth. The second is the establishment of physiologic architectural relation-

ships. The elimination of the disease process does not necessarily establish lasting functional health, but correct architectural form is necessary. In reality, the two objectives of periodontal therapy are one. The procedures used to obtain both usually are performed simultaneously.

The treatment of the marginal lesion should result, ideally, in no gingival crevice and in an accepted combined morphology of the tooth and gingivae. Therapy of the attachment apparatus should result in physiologic distribution of occlusal stresses, accompanied by healing of the traumatic lesions.



A.

B.

C.

Fig. 8.—*A*, The full upper quadrant of teeth are prepared for splinting. *B*, The temporary acrylic resin fixed partial denture was constructed at the chair. *C*, The temporary fixed partial denture is cemented in the mouth. Three of the seven abutments had varying degrees of mobility. The splint offers pulp protection to prepared teeth, physiologic stress distribution through balanced occlusion, gingival protection as a result of biologic crown form, and necessary rigidity for the stabilization of the mobile teeth to promote healing of the traumatic lesions.

The origin of the periodontal pocket should be established. Most dentists believe that only marginal irritation, not traumatic occlusion, is responsible for pocket formation.[17,18,19] One thing is certain: no amount of occlusal equilibration or periodontal prosthesis is capable of eliminating a periodontal pocket. The techniques of scaling, curettage, gingivectomy, gingivoplasty,[20] odontoplasty,[21] osteoectomy,[22,23] osteoplasty,[24] and mucogingival surgery[25] may be necessary for pocket elimination (Figs. 9, 10, 11, and 12).

Fig. 9. Fig. 10.

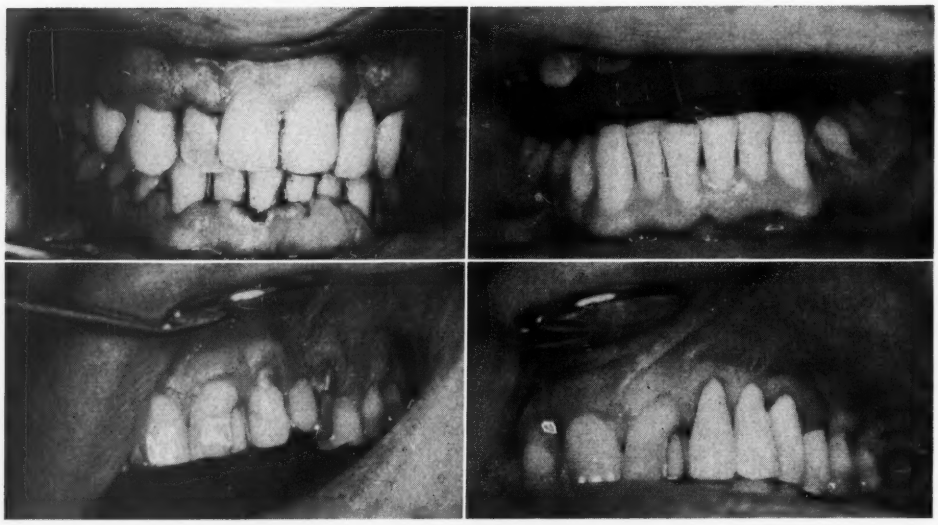


Fig. 11. Fig. 12.

Fig. 9.—A patient with chronic Vincent's disease.

Fig. 10.—The treatment included gingivectomy, gingivoplasty, and osteoplasty. Note the change in architectural form.

Fig. 11.—The marginal periodontitis was complicated by a complete loss of the attached gingiva. The first bicuspid is the abutment for a cantilever fixed partial denture.

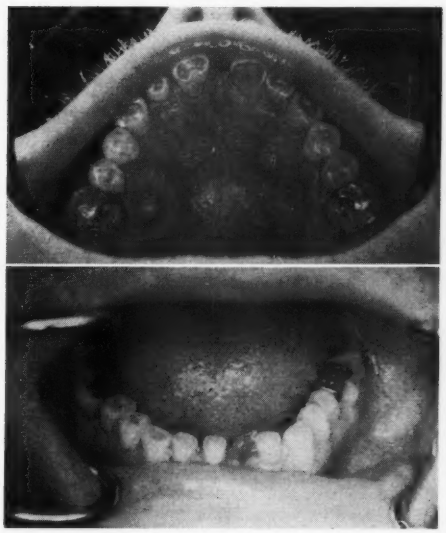
Fig. 12.—Mucogingival surgery was performed. Note the regeneration of a mucogingival line demarcating the unattached from the newly formed attached gingivae. The lateral incisor and the two biscupids were utilized for abutments to replace the missing cuspid. This stabilized the segment.

Periodontal disease is caused primarily by local environmental factors. Systemic factors, however, do play a role and for a few patients the major role.[26] The influence of systemic factors is evident in mouths where local predisposing factors are not commensurate with the degree of periodontal involvement.

ESTABLISHING THE CORRECT VERTICAL DIMENSION OF OCCLUSION

A change in the vertical dimension of occlusion may be necessary occasionally because of advanced crippling or collapse of the dental apparatus. Any increase in an existing vertical dimension of occlusion must be made with extreme prudence. Any impingement upon the interocclusal space will result inevitably in failure.[27] Landa denounces the use of the term "free-way space." He maintains the term "interocclusal space" should be used.[28] The "free-way space" is an abritrarily conceived 2 to 3 mm. space representing the *average* distance between the incisal edges of the upper and lower anterior teeth when the mandible is in the physiologic rest position. This position is an anatomic and functional entity differing greatly among individuals. The interocclusal space varies from 1.5 to 8 mm. An arbitrary average of 2 to 3 mm. cannot be used as a basis for restorative procedures. Some individuals require more and others less of this arbitrary space for optimum efficiency in mastication, speech, esthetics, and neuromuscular adaptation.

A.



B.

Fig. 13.—*A* and *B*, A dentition where restoration of the vertical dimension of occlusion was necessary.

Fig. 14. Fig. 15.

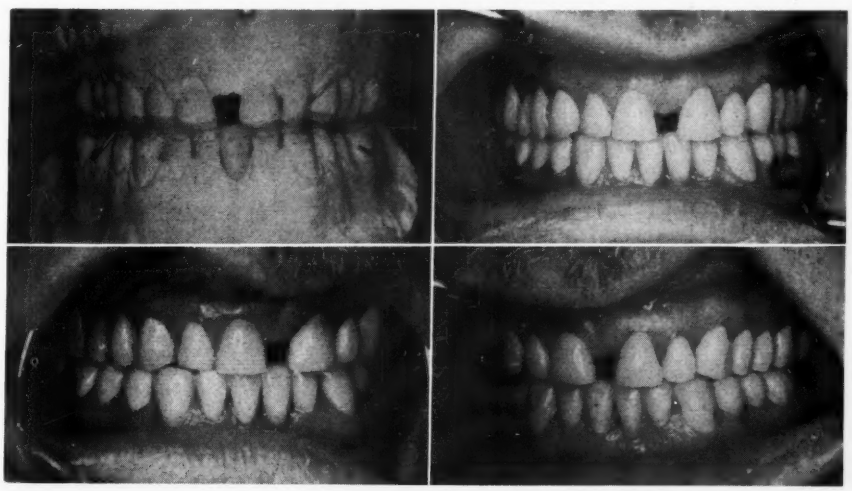


Fig. 16. Fig. 17.

Fig. 14.—The temporary splints cover the patient's teeth. Note the equal distribution of the restored dimension to both dental arches.

Fig. 15.—The centric occlusion upon completion of the case as seen in Fig. 13.

Fig. 16.—The right working tooth contacts of the patient as seen in Fig. 13.

Fig. 17.—The left working tooth contacts of the patient as seen in Fig. 13.

The method of ascertaining physiologic rest position is relatively simple.[29] An awareness of psychogenic manifestations, however, is important.[30]

The technique for restoring the vertical dimension of occlusion is accomplished by trial acrylic resin splints, one for each dental arch (Figs. 13, 14, 15, 16, and 17). The splints must occlude correctly in centric relation. A trial period of 2 to 6 months is usually necessary to elicit important information regarding tissue tolerance, joint and functional accommodation, and esthetics of face form.

MINOR ORTHODONTIC CORRECTIONS

Teeth which present a deficient axial relationship to basal bone or poor contact relationships to adjacent teeth are often poor risks as abutments for occlusal rehabilitation. When mass anchorage is required for proper alignment of teeth, patients are treated best by an orthodontist. When a tipping movement is sufficient,

Fig. 18.

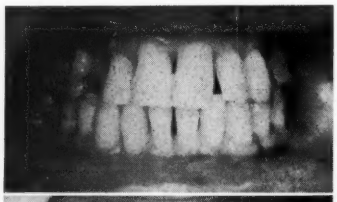


Fig. 19.

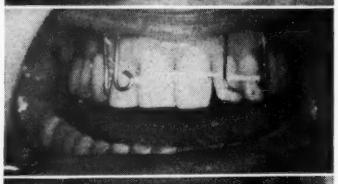


Fig. 20.

Fig. 18.—The upper dental arch requires a full splint because of the severity of the original periodontal condition. The arrangement of the anterior teeth makes abutment preparation impossible without endangering the vitality of the teeth.

Fig. 19.—A modified Hawley appliance was used in conjunction with rubber dam elastics.

Fig. 20.—The anterior teeth are in proper alignment for full dental arch splinting.

however, malposed teeth often may be treated successfully by wire and silk ligatures or by rubber dam elastics with or without some modification of the Hawley appliance (Figs. 18, 19, and 20).[31,32]

Sufficient space must be available or created for the moved tooth, and the forces which have caused the tooth to move into its present poor relationship must be eliminated. Detrimental habits must be eradicated or diminished.

FURTHER OCCLUSAL EQUILIBRATION

Complete occlusal equilibration of the natural or artifical teeth is accomplished before permanent prostheses are constructed. This results in a physiologic environ-

ment for the reception of any necessary prosthesis. Competent laboratory and clinical procedures produce a completed rehabilitation requiring, at most, simple spot grinding.

The next step in occlusal equilibration is the establishment of an incisal guidance which is compatible with posterior cuspal inclines. The inclines must not introduce stresses exceeding physiologic tolerance. The best technique is to change the lingual inclination of upper anterior teeth from the point of contact in centric relation. In some instances this technique may have to be combined with others to produce the required relationships.

The final consideration is the establishment of an acceptable excursive and positional contact of related cusps during the limits of functional movements of the mandible. Simultaneous contact of all teeth in eccentric positions is rarely necessary. A group function is provided to physiologically distribute occlusal stresses in these excursions.

PROSTHETIC CONSIDERATIONS

The prime aim of a prosthesis is not the replacement of missing teeth. The most important function of a prosthetic restoration is the stabilization of the remaining teeth, especially the abutment teeth, against destructive forces.[33]

Teeth tolerate intrusive forces best, because of the architectural arrangement of the periodontal fibers. Lateral stresses are tolerated least, especially when teeth have been involved periodontically. The stabilization of abutment teeth or, if necessary, of the complete dentition to enable them to withstand lateral stresses adequately is the major consideration in planning a prosthesis.

The method used for attaching a prosthesis is probably the most important single factor affecting the prognosis of any rehabilitation. Three methods of attachment are available. These are removable clasp partial dentures, removable internal precision attachment partial dentures, and fixed partial dentures.

The removable clasp partial denture is the least desirable. Biologic stress distribution is difficult and rarely obtained. When used, the one-piece, rigid casting is tolerated best. Bilateral distribution of functional stress is thus possible.[34] The great fault of dentures with clasps is that it is virtually impossible to design all clasp arms in the same horizontal plane. As a result, buccolingual movement of abutment teeth always occurs upon insertion. Furthermore, tensional differences always exist when the denture is in place, since any combination of clasps must spring over tooth contours and engage undercut areas for retention. This places teeth under tension which the periodontal membrane must absorb, and the stresses often exceed physiologic limitation. Another detriment is the lack of a precise method of adjustment. Tightening a clasp often induces increased tension on the periodontal membrane due to disfiguration of the bracing and/or retentive portions of the clasp.

When a removable partial denture is a necessity, the internal precision attachment partial denture is the most desirable. Difficulties encountered with clasp-retained dentures are surmounted. Since the center of rotation of a tooth carrying an attachment is much closer to the actual center, functional stress is resolved into a vertical intrusive force. Without circumferential pressure, supporting structures

are under stress only during function. The insertion and removal are limited to one exact path which places no stress on abutment teeth during these operations. Furthermore, the adjustment of a loose attachment is performed in a precise manner incapable of introducing occlusal or denture base distortion.

The ideal tooth replacement is the fixed partial denture. A single abutment at either end of the edentulous space may not, however, be sufficient for buccolingual stability. Added splinted abutments may be necessary. If the available teeth on one side do not accomplish the required stability, then utilization of further abutments around the curvature or *across* the dental arch may be a necessity. When teeth are splinted, a multirooted unit is created which does not harm the stronger members.[35] Such fixation allows for periodontal repair of injured teeth. There is no hard and fast rule governing the number of firm teeth necessary to stabilize mobile teeth. Many other principles of occlusion, as well as axial relationships, must be considered.[36,37,38]

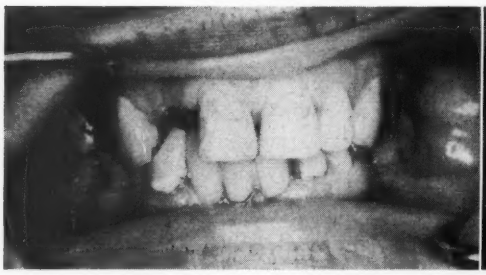


Fig. 21.

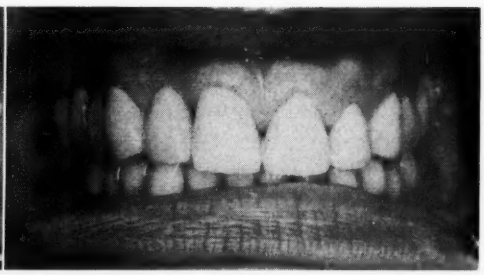


Fig. 22.

Fig. 21—A mouth with advanced breakdown of the dental apparatus.
Fig. 22.—Occlusal rehabilitation employing the treatment plan outlined was used. Each dental arch required complete permanent splinting. All of the phases of the treatment plan were employed.

PLACEMENT OF RESTORATIONS

The fixed part of the occlusal rehabilitation is inserted temporarily with an appropriate cement[39] for a period of 1 to 2 years. This assures easy removal and clinical examination of questionable teeth. Removal of these teeth, if necessary, becomes a simple procedure.

After stabilization has occurred and a favorable response in the attachment apparatus has been established, permanent cementation may be undertaken.

INSTRUCTIONS IN ORAL PHYSIOTHERAPY FOR HOME CARE

The final phase of any occlusal rehabilitation is adequate instruction for home oral physiotherapy. The particular method of tooth brushing suitable for the patient should be demonstrated. Periodically the patient's versatility in the proper handling of the brush and the rubber tip stimulator should be checked by the dentist to be certain that the patient has understood and applied the instructions.

SUMMARY

A plan for treating both the incipient and the deeply involved debilitated dentitions has been presented. The use of biomechanical principles has been stressed (Figs. 21 and 22).

The oral conditions and their degree of breakdown may warrant changes in chronologic order of the procedures. Some mouths may require different procedures at different times or a simultaneous integration of many procedures at the same time.[40]

I wish to express my sincere appreciation to Dr. H. H. Pearson of Montreal for his guidance in the organization of my material.

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CONSERVATIVE OCCLUSAL REHABILITATION

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DISREGARDING CERTAIN basic limitations and orthodox procedures in the treatment of dysfunctioning occlusions contributes to major failures. Occlusions are like fingerprints; no two are exactly alike. The occlusions of the teeth are established in functional harmony with the muscles, nerves, ligaments, and temporomandibular joints. The arrangement of the natural teeth may be prognathous, protrusive, or of different levels and yet be normal for the individual, because Nature is not concerned with symmetry. Nature creates a mouth primarily for function and as long as the occlusion functions satisfactorily, without pain or discomfort and without damage to the supporting structures, no change in the pattern of occlusion is necessary despite excessive vertical and horizontal overlaps or different waves and levels of occlusion.

Disturbing a functioning occlusion by the wanton destruction of teeth for full coverage restorations, the indiscriminate splinting of teeth, and the "raising of a bite" under the guise of restoring an occlusion are serious errors in treatment. Reconstruction is not necessary just because the occlusion present does not conform to a pattern accepted as ideal by the dentist. Uniformity of teeth, uniformity of occlusal carvings, and undeviating curves of occlusion do not exist. To change an occlusion so that these manifestations follow one particular pattern of contour and design does not always prove successful. As a result, man-made corrected occlusion is frequently incompatible with the patient's manner of chewing, with his tolerance to any change, and with the osseous and neuromuscular asymmetries of the jaws and teeth.

One individual does not react to dental treatment in exactly the same way as another. We should not, therefore, recommend for all patients one procedure for correcting dysfunctioning occlusions, derived solely from a pattern based on theoretic philosophy.

THE TEMPOROMANDIBULAR JOINT

In occlusal rehabilitation, too much emphasis is placed upon the temporomandibular joints, the hinge-axis recording, and the articulator. The joints are not the predominate factor, and to say that they dictate the movements of the mandible is putting the cart before the horse. The temporomandibular joint is not precise like a door on a hinge or like a ball in a socket. The convexity of a ball conforms closely and uniformly to the concavity of the socket, whereas the odd-shaped condyle is incongruent with the fossa. The mandible is suspended in a hammock of muscles

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and ligaments. The condyles are separated from the fossae by articular discs, cushioned and loosely sandwiched in between synovial membranes and fluid. The movements of the mandible are different in each individual. The movements are dictated and controlled by the nerve centers in the brain, by the musculature, and by the proprioceptors that yield reflex actions to determine the positions of the jaw.

THE HINGE AXIS

Orientation of the maxillary working cast to the articulator is a distinct advantage in occlusal rehabilitation. Hundreds of articulators and face-bows are in use and there will be many more developed.

An articulator is an instrument of personal preference to accomplish an end. It is not necessary or always possible to record minute, accurate measurements in locating the hinge axis of the mandible. The human jaw should not be considered a mechanical hinge, with geometric circular condyles revolving like balls in sockets around a hypothetical axis, in the skull of a metal robot. The mandible is unique in its individual movements and is capable of millions of movements that cannot be registered mathematically or transferred unerringly to a mechanical contrivance. I place no importance on the hinge-axis recording but, to quote Boucher,[1] ". . . if its proper location and transfer helps those who emphasize its importance to provide better occlusion for their patients, it [the hinge-axis recording] is worth while."

BASIC REASONS FOR FAILURE IN OCCLUSAL REHABILITATION

Unsuccessful results in occlusal rehabilitation have not been caused by the use of, or the failure to use, a specific instrument, a hinge-axis recording, or any other registration. Some occlusions are best left alone. Others should be treated conservatively, and some harmonious functional occlusions are duplicated best in oral reconstruction. The three main reasons for failures are (1) an increase in the vertical dimension of occlusion beyond the limits of the physiologic rest position, (2) the rehabilitation of an occlusion in a natural dentition following the concept of a nonphysiologic, "balanced" occlusion, and (3) a disregard for, or the inability to recognize, the limitations in and around the mouth and of the materials used in restorations. Satisfactory results can be accomplished by utilizing simple and practical methods with consideration for these three basic factors.

THE VERTICAL DIMENSION OF OCCLUSION

Recording the vertical dimension of occlusion for restoring teeth of a natural dentition is different in many instances from recording that dimension for complete dentures. Many natural dentitions requiring rehabilitation possess a satisfactory, tolerant, and functional centric occlusion (Fig. 1). Centric occlusion is the most important concern of occlusal rehabilitation; there is no need to destroy that position and then resort to the arbitrary method employed for complete dentures to restore the relationship. Once the tolerated and correct vertical dimension of occlusion is lost or destroyed, it is almost impossible to record the correct one again. The sooner we separate the treatment of occlusion in dentitions from that used in complete dentures,

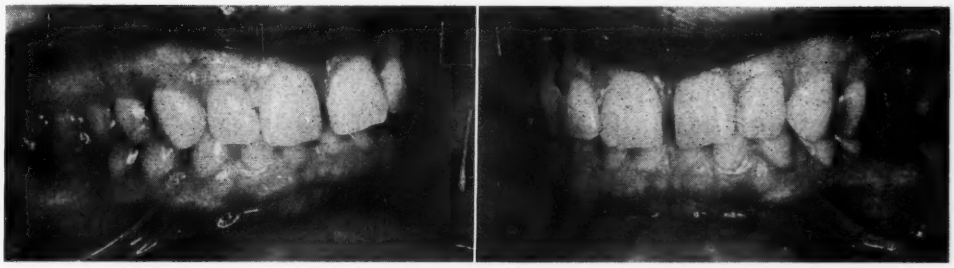

Fig. 1.—It is not necessary to prepare all of the teeth in one jaw first and destroy the centric occlusion, then resort to methods employed for making complete dentures to restore that relationship.

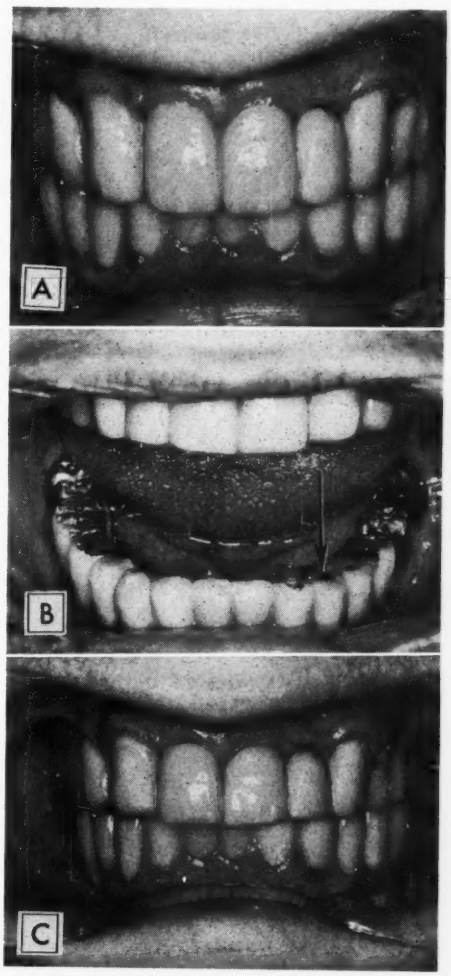

Fig. 2.—*A*, This occlusion was rehabilitated using the 2 to 3 mm. average interocclusal distance. The patient suffered pain and discomfort. *B* and *C*, The height of the restorations was reduced until comfort and freedom from pain were achieved for the patient. The resultant interocclusal distance was found to be approximately 6 mm.

the more conservative and the more successful will be the rehabilitation. When the occlusion is incorrect and damaging in complete dentures, the dentures can be remade without discomfort and pain to the patient. When multiple and extensive fixed restorations are cemented permanently and the occlusion proves damaging, however, their removal and reconstruction are tedious, painful, and uncomfortable.

The interocclusal distance of all patients is not the same. The 2 to 3 mm. measurement is a statistical average and cannot be used as the exact criterion, only as a starting point (Fig. 2). The patient's speech, esthetic appearance, comfort, and tolerance limit determine just how much interocclusal clearance is necessary. Just because the patient's interocclusal distance may be greater than 2 to 3 mm., this does not make it permissible to increase the vertical dimension of occlusion beyond the limits of that patient's physiologic rest position.

When there is a loss of vertical dimension of occlusion, however, we record the vertical dimension in the same manner as for complete dentures. The average measurement is used as a starting point only. Another factor must be considered when there is a decrease in the vertical dimension of occlusion because of excessive wear of the occlusal and incisal surfaces of the teeth. To restore the vertical dimension for such patients by methods used only for complete dentures will not take into consideration the *uncontrollable* habit of bruxism. It is frequently necessary to construct a fixed or removable splint with the natural functional occlusal curves and with a slight increase in the vertical dimension of occlusion to ascertain how much of the lost dimension can be restored and tolerated. When the point of comfort is reached, the splint is set aside to be used as an occlusion rim after the teeth are prepared.

In other occlusions, natural opposing teeth contribute to a satisfactory occlusal relationship. These occluding teeth can be used as guides or stops in maintaining the satisfactory occlusion while restorations are being made on the other teeth.

THE OCCLUSAL CURVE

The occlusal curve of a natural dentition does not always follow the average curvature described by von Spee, Monson, and others. The difference in the occlusal cant is caused by one of three factors: (1) the developmental arrangement of the natural teeth, normal for the individual, (2) the exfoliation or extrusion of teeth as a result of failure to replace missing opposing teeth, abnormal for the individual, or (3) the wearing down of the occlusal and incisal surfaces by bruxism which results in characteristic occlusal patterns and subsequent changes in the occlusal curvature, normal for the individual.

A developmental curve in an occlusion requiring rehabilitation should not always be changed. The rehabilitation is more likely to be tolerated by the patient if the developmental occlusal curve is duplicated. When elongated teeth contribute to an abnormal curve, however, these teeth must be reduced or even removed, and the occlusion can be restored by following the principles of von Spee, Monson, or Hanau. The functional curve of occlusion created by wear is a topic of much discussion and indecision.

What is eaten and how it is eaten are the results of necessity and habit. Man's occlusion is multifunctional because it manages all types of food. A change in occlusion occurs for some people as they approach middle age. This change is an individual manifestation which is pronounced in some patients, insignificant in others. The different relationship may be attributed to the wear of the occlusal and incisal surfaces brought about by bruxism or the abrasive action of the food.

The factor of coarse, gritty foods plays a small part in creating flatter cusps and in changing the occlusal curvature; the symptom of bruxism can be considered as a predominately abnormal phenomenon. The latter removes cuspal interferences

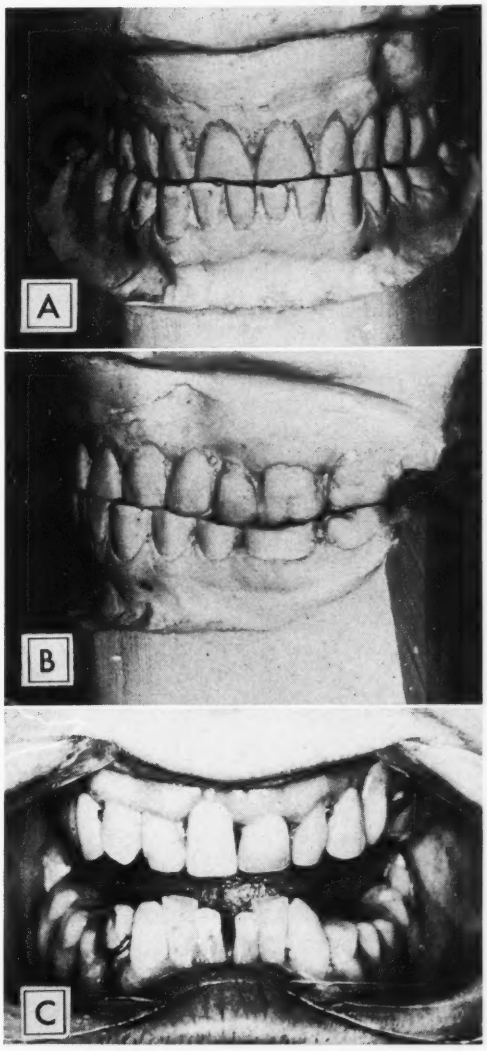

Fig. 3.—*A* and *B*, Wear caused by bruxism brings about an edge-to-edge occlusion and a change in the occlusal curvature in some patients. This occlusal curve should be duplicated in occlusal rehabilitation to prevent interference during bruxism. *C*, Removable partial dentures were abraded by bruxism to a tolerant, comfortable, functional occlusal curvature.

and brings about an edge-to-edge occlusion as well as a different occlusal curvature (Fig. 3). The curve is created by abnormal, excessive wear and often assumes a position contrary to the curves of von Spee or Monson. Function is not impaired, because low or even flat cusp teeth masticate food satisfactorily. The patient may not

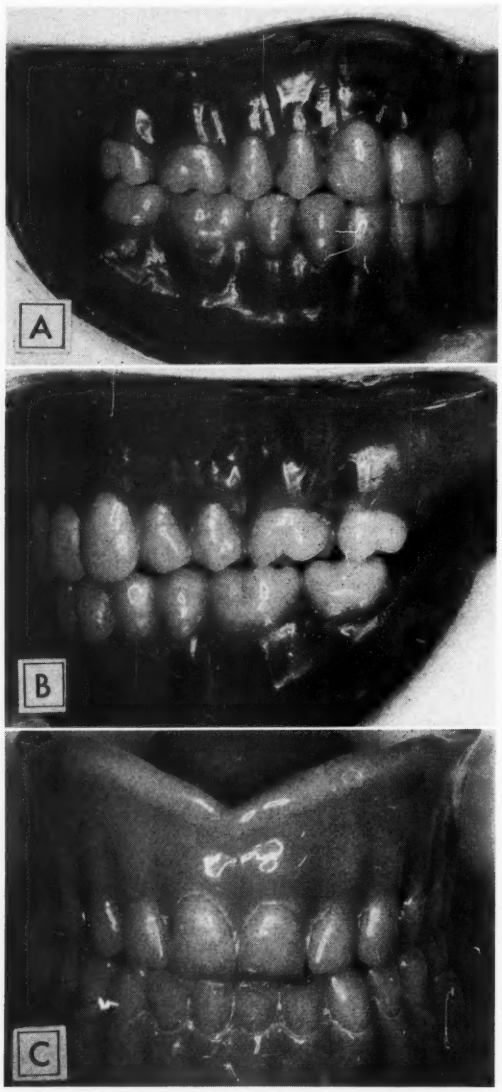

Fig. 4.—Balanced occlusion applies only to complete dentures and is considered necessary for denture stability. *A*, The working side, *B*, the balancing side, and *C*, the protrusive position with the incisal and occlusal areas in contact.

be able to shred his food as well because of the lack of cusps (the sharp enamel rims of the facets accomplish the same result as cusps), but he is able to pulverize and triturate the bolus more efficiently. At the same time he is able to carry out the un-

controllable movements of bruxism without interference. This functional curve is sometimes characterized by comfort without damage to the supporting tissues, in that wear to the teeth is substituted for injury to the underlying bone. The muscles of mastication have guided the mandible by habit, not with a "balanced" but with a harmonious occlusion, in mulling and crushing the food. It would be inconvenient if the functional curve were changed.

I have more faith in a natural functional curve for such a patient than in a theoretic one, obtained arbitrarily and created with tripping cusps. When the occlusal curve of such a patient is changed according to the recommendations of von Spee or Monson, the powerful influence of the grinding habit is disregarded. The neuromuscular system, with its habits and memories, frequently resists the new job when the functional curve is altered. The patient is prone to remark, "Doctor, it feels as though I'm chewing on pebbles." Mouth rehabilitation changes the physical conditions but does not always succeed in changing the habits that previously produced comfort. New patterns of function have to be learned by patients and they may find it difficult.[2]

I do not recommend that all functional curves be duplicated. But if the occlusal curve is not a factor in temporomandibular joint disturbances, if it contributes to a healthy periodontium, if it participates in a comfortable and functional occlusion, then it is advisable to duplicate that curve in occlusal rehabilitation. We are qualified to remedy, not create, occlusions.

THE FALLACY OF A "BALANCED" OCCLUSION IN A NATURAL DENTITION

In occlusion in modern man the teeth overlap. With some reservations, this can be considered the most natural type of articulation. This situation, along with the interrelating arrangement of the anterior teeth, limits lateral and protrusive excursions when the teeth are in contact. I do not record protrusive and lateral movements when rehabilitating a dentition, because I am not concerned with balancing contacts.

The most significant step in occlusal rehabilitation is producing a "balanced" occlusion. This is a hazardous recommendation because of the ambiguity of the term. According to the *Glossary of Prosthodontic Terms,*[3] a balanced occlusion is "the simultaneous contacting of the upper and lower teeth on the right and left and in the anterior and posterior occlusal areas. This occlusion is developed to prevent a tipping or rotating of the denture bases in relation to the supporting structures" (Fig. 4). The definition applies, however, only to complete dentures.[4] Are we to understand then that all mouths requiring occlusal rehabilitation should be so corrected as to be like complete dentures? In most natural dentitions that function satisfactorily, there is no working-side, balancing-side arrangement of teeth (Fig. 5).

Occlusion in a natural dentition should not be treated according to so-called balanced occlusion if contacting opposing teeth are in satisfactory centric occlusion despite the fact that anterior teeth in contact prevent lateral movement (Fig. 6). An occlusion that functions primarily in a vertical direction is a healthy occlusion. A natural dentition may intercuspate in gliding movements unilaterally, but neither

protrusive nor bilateral balance is required. A compatible distribution of stress on the working side is desirable, without the necessity of the teeth touching on the opposite side. When we speak of balanced occlusion in a natural dentition, we speak of a harmonious occlusal arrangement peculiar to one individual. We should not compare something that differs in each individual to a uniform, contacting arrangement of restored teeth.

We should distinguish between interfering cusps and balancing contacts in all excursions. Not all deflective occlusal contacts interfere with occlusion. There is no need to reduce healthy, natural anterior teeth so that the patient can slide into a working-side, balancing-side arrangement (Fig. 7). The grinding of deflective occlusal contacts can become a continuing procedure, because it is easy to grind but difficult to know when to stop grinding. When a deflective contact does damage it is an interference, and all interferences must be removed judiciously.

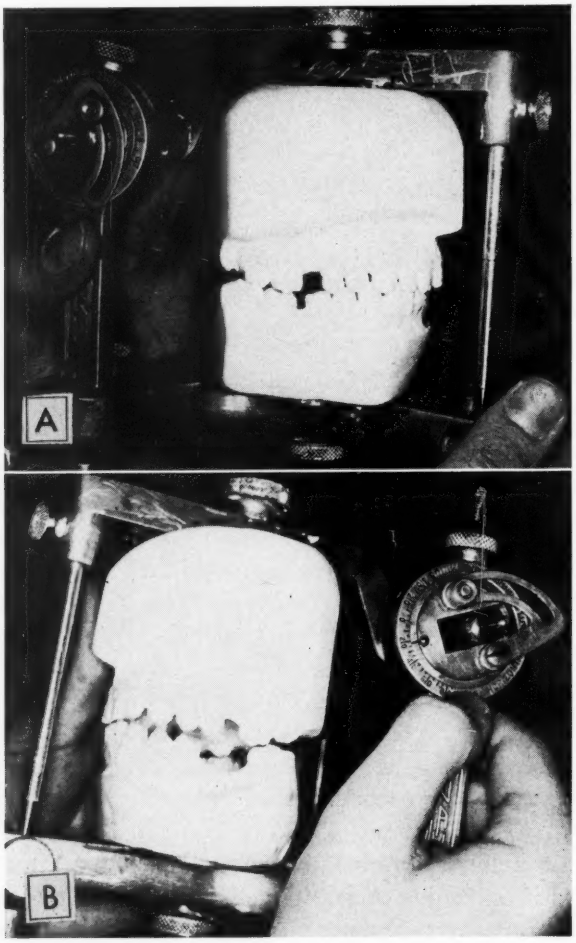

Fig. 5.—*A*, The teeth on the working side of a natural dentition are in contact. *B*, The teeth on the balancing side are not in contact.

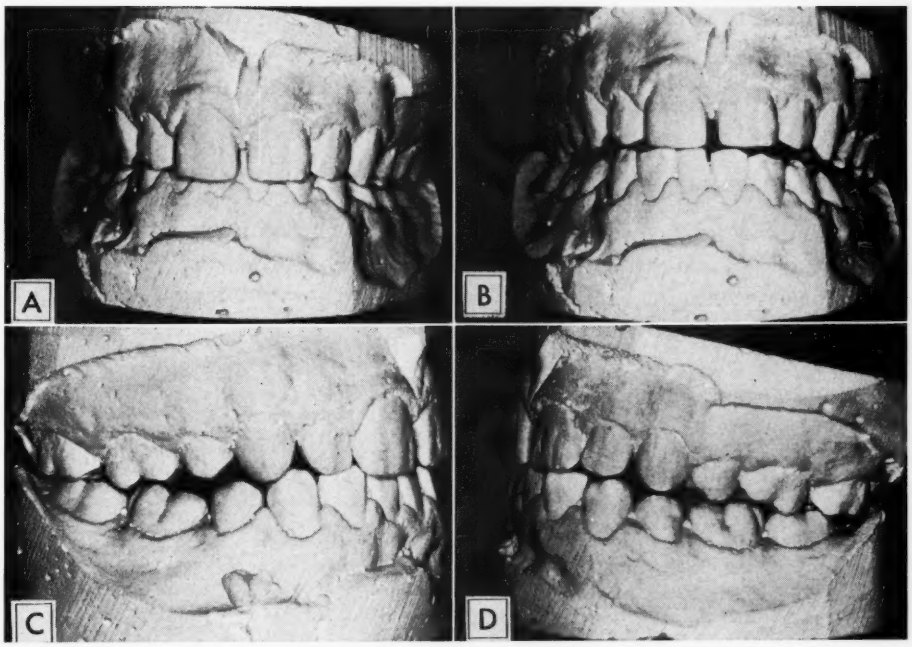

Fig. 6.—Casts of a natural dentition of a 25-year-old patient. *A*, The centric occlusion, *B*, the protrusive occlusion with the posterior teeth not in contact, and *C* and *D*, the right and left balancing sides with the molar teeth not touching.

Fig. 7.—The canine tooth prevents lateral excursions with the teeth in contact. Reduction of the anterior teeth is not necessary to permit sliding into a working-side, balancing-side arrangement. Esthetics and the vitality of the anterior teeth would be jeopardized.

There is no mathematical gadget which will select the angle of cusps indicated for an individual patient. A jaw that functions in a chopping, up-and-down motion requires restorations which are in harmony with these movements. Usually these teeth have deeper cuspal inclines, and the interdigitating cusps should be duplicated. To sacrifice these cusps by constructing flat occlusal planes so that the teeth can slide into lateral balance jeopardizes the vitality of the anterior teeth as well as the esthetics. Whenever I constructed restorations with deep cuspal inclines, however,

invariably I had to reduce them so that the patient could tolerate the rehabilitation. Restorations with low cuspal inclines and deep sluiceways on the occlusal surfaces have proved more successful than completely flat or "picture-book," ideally constructed cusps.

TEN DIFFICULTIES IN OCCLUSAL REHABILITATION

Before the dentist commits himself to altering an occlusion, he must be convinced that the conditions present do not prevent or limit that change. The conditions that make successful treatment difficult are (1) occlusion of different levels, (2) occlusion with an excessive vertical overlap, (3) occlusion with a horizontal overlap (overjet), (4) occlusion with a prognathous mandible, (5) occlusion with mobile teeth, (6) occlusion influenced by wear due to bruxism, (7) occlusion with an anterior or posterior cross-bite, (8) occlusion with abnormal tongue and swallowing habits, (9) occlusion treated previously, and (10) abnormal but functional occlusion of convenience.

Occlusion With Different Levels.—An occlusion with different occlusal levels may be satisfactory (Fig. 8, *A*). When these normal occlusions are altered the result may be a disaster because of the attempt to follow the pattern of uniform occlusal and compensating curves used in complete denture occlusion. Leveling the occlusal plane of the mandibular posterior teeth with that of the mandibular incisors can be accomplished only by increasing the vertical dimension of occlusion beyond the limits of tolerance. When such an occlusion requires restorations, the pattern of different levels should be duplicated. This normal occlusion type must not be confused with the abnormal type in which there are different levels created by extrusion of teeth, due to failure to replace missing opposing teeth.

Occlusion With Excessive Vertical Overlap.—The second type of occlusion which should not be altered is one with an excessive vertical overlap (Fig. 8, *C*). When such an occlusal relationship is due to developmental phenomena, correction can be accomplished only by increasing the vertical dimension of occlusion beyond the limits of the physiologic rest position. Sometimes a patient with such a marked overlap exposes a lot of gingival tissue when smiling. Such a patient thinks that occlusal rehabilitation will improve the condition and he will make unreasonable demands. When the overlap is excessive because of the loss of all posterior teeth in one or both jaws, some reduction of the overlap may be accomplished by restoring the lost vertical dimension. When the overlap in patients of middle age is aggravated by a pathologic periodontal condition or by missing or mobile teeth, conservative treatment is advisable. In most instances, however, rehabilitation procedures should retain the vertical overlap.

Occlusion With Marked Horizontal Overlap.—The third type of occlusion which is better left unchanged is one with an excessive horizontal overlap (overjet) (Fig. 8, *D*). Correction by rehabilitation is not indicated when there is a marked anteroposterior difference in anatomic size of the mandible and the maxillae. Orthodontic treatment rarely accomplishes an improvement, partciularly for patients of middle age. Here again the patient is concerned primarily with esthetics, the protruding maxillary teeth, and the retruding chin. Mouth rehabilitation procedures

by means of crowns and fixed partial dentures cannot "grow a chin," and the patient should be so advised. To "reposition" the mandible by increasing the vertical dimension of occlusion and to recommend that the patient project the mandible forward to assist in the so-called repositioning are primary reasons for failure. The comfortable vertical dimension of occlusion should be maintained, and the anterior occlusal relationship should be duplicated in the restorations.

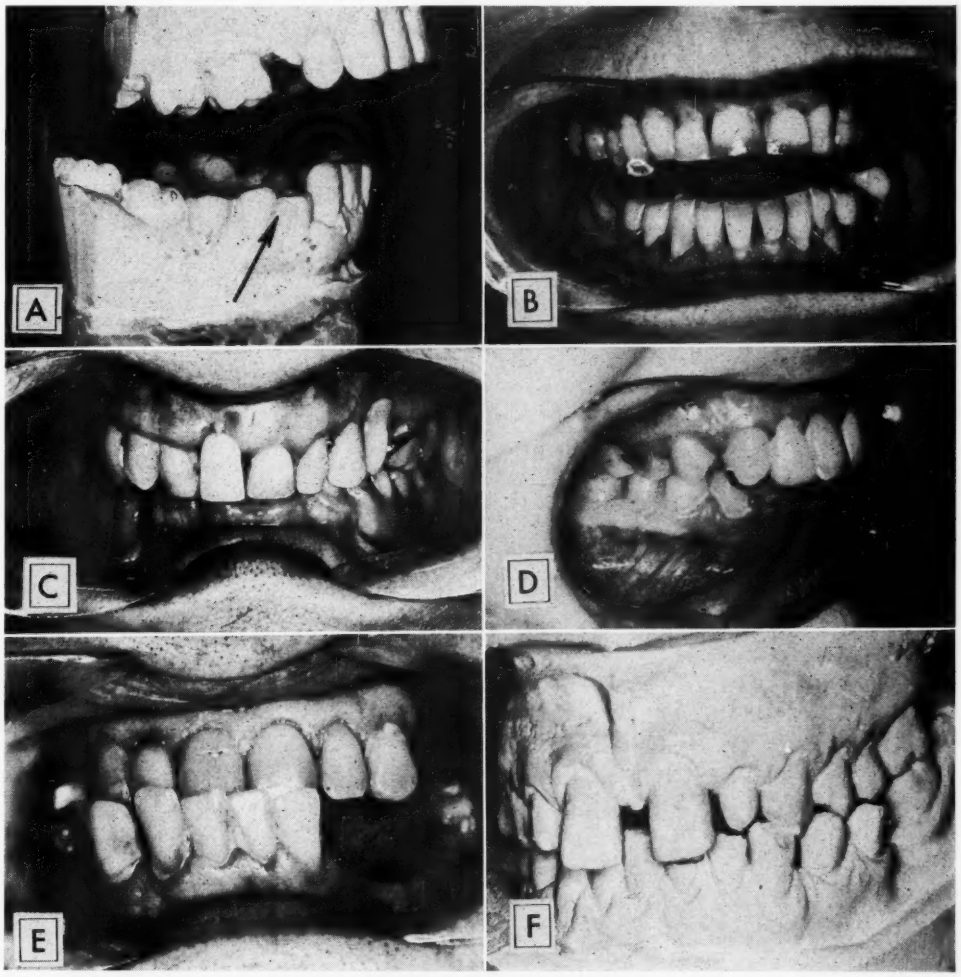

Fig. 8.—Some occlusions that resist the usual corrections in occlusal rehabilitation. *A*, A type with the occluding surfaces at different levels. Leveling the mandibular posterior teeth with the incisors can be accomplished only by increasing the vertical dimension of occlusion beyond the limits of tolerance. In the rehabilitation of such a situation it is advisable to maintain these different levels. *B*, An occlusion with mobile teeth. *C*, An occlusion with a marked vertical overlap brought about by developmental phenomena should not be reduced by rehabilitative procedures. *D*, An occlusion with a marked horizontal overlap due to anteroposterior difference in anatomic size of the maxillae and the mandible. Repositioning the mandible by increasing the vertical dimension will only end in failure. *E*, an occlusion with a prognathous mandible. This true prognathous occlusion is one with a marked anteroposterior difference in the anatomic size of the jaws. The same relationship should be maintained in occlusal rehabilitation. *F*, An occlusion with a cross-bite. If the cross is a tooth-to-tooth relationship, it may be possible to make the correction with crowns. If the condition is an interarch relationship, correction by prosthodontic means is contraindicated.

Occlusion With Abnormal Tongue and Swallowing Habits.—An occlusion influenced by abnormal tongue and swallowing habits may not be recognized by the dentist. An oversized, muscular tongue exerts a powerful force, usually against the anterior teeth. This abnormal pressure contributes to a fanning and subsequent separation of the anterior teeth. Sometimes the influences of the tongue and swallowing habits begin in childhood, and the forces affect the bone as well as the teeth. The unesthetic change in the position of the teeth is gradual, and when the patient of middle age requests esthetic improvement the dentist should not commit himself about the success of the treatment. The dentist must scrutinize the study casts, the tongue, and the swallowing habits. Reducing the vestibule by bringing the anterior teeth back by orthodontic treatment will trap the tongue temporarily. Splinting the teeth together is of no advantage, and rehabilitation will fail because the powerful tongue will force the restored teeth, splint and all, out of the corrected alignment. Consideration must be given to a tongue that exerts such force and the patient must be advised of the limitations of the treatment.

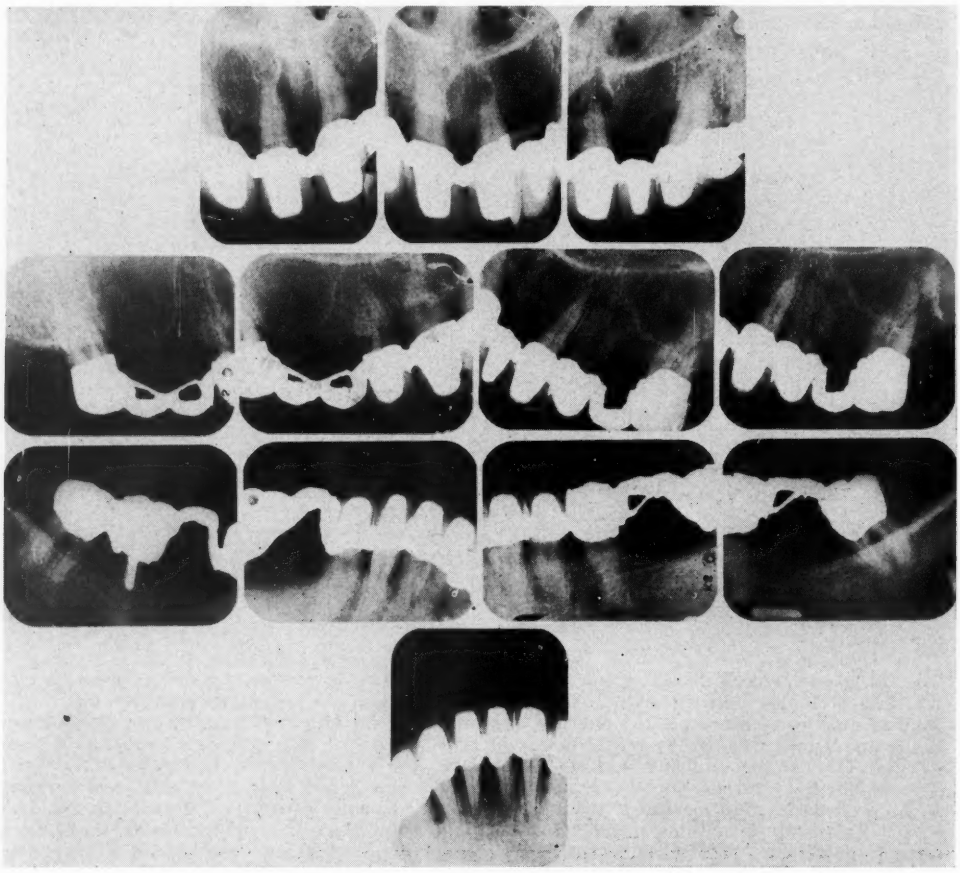

Fig. 9.—Roentgenograms of splinted restorations on mobile teeth. Note the unequal ratio between the clinical crown length and the root length. The patient should be forewarned that the period of usefulness of extensive restorations may be short.

Occlusion With a Prognathic Mandible.—The fifth type of occlusion which should not be altered is the prognathous one. A true prognathism is one with marked anteroposterior difference in the size of the maxillae and the mandible (Fig. 8, *E*). Maxillary restorations on the anterior teeth must be oversized in order to "jump" the anterior teeth after the vertical dimension of occlusion is increased. These procedures seldom prove satisfactory. Facial expressions become less pleasant because the contour of the anterior teeth is increased by a labial tilt incongruous with the typical short upper lip. These contours are incompatible with the musculature, and grimaces result. The deflecting contours between the gingivae and the restored teeth are altered and food debris collects around the necks of the slanted teeth. When the occlusion is increased and the jaw performs lateral excursions, function is impaired because of the drastic change in the patient's manner of chewing. Any attempt at esthetic improvement usually does not succeed in pleasing these patients, because they want a reduction in the chin that cannot be accomplished by dental restorations.

Occlusion With Mobile Teeth.—The sixth type of occlusion which cannot be successfully rehabilitated is that with mobile teeth (Fig. 8, *B*). Correct periodontal treatment and fixation of slightly mobile teeth may be accomplished if the teeth have a chance to tighten. Splinting of these teeth, however, involves some difficulties. Sufficient tooth structure to accommodate the thickness of the metal plus the thickness of the veneer cannot be removed from thin anterior teeth. More often the original anatomy of the teeth cannot be duplicated because of the patient's demand for esthetic improvement. Bulky restorations are the result.

Building elaborate structures on poor foundations is an impractical undertaking (Fig. 9). The periodontist should be more conservative in his recommendations to splint teeth, particularly when the responsibility for the restorations rests upon another dentist. Most mobile teeth are not conducive to successful rehabilitation when bone loss is severe. The patient should be forewarned that the period of usefulness of extensive restorations may be short.

Occlusion Influenced by Wear Due to Bruxism.—The seventh kind of occlusion that is difficult to rehabilitate is one aggravated by the habit of bruxism, which often is symptomatic of a psychologic syndrome. The removal of the symptom will not eliminate the cause; a new symptom, more severe in nature, will manifest itself elsewhere (Fig. 10).

Habits of bruxism create certain characteristic patterns of wear. These patterns must be accommodated, and for some patients duplicated, in the restorations. The dentist must recognize the various types of wear patterns so that the restorations will be compatible with the abnormal mandibular movements. Patients who practice bruxism cannot tolerate a new occlusal relationship which does not take into consideration the uncontrollable habit that produces the wear pattern.

The wear patterns cause facets with sharp enamel rims, ledges or grooves, or scissors-type, half-moon, V-shaped, or so-called uniform flat wear forms, or any combination of these. Occlusal rehabilitation will not cure the patient of bruxism, and splinting of teeth often aggravates the habit.

Occlusion With a Cross-bite.—It is impractical to change an occlusion with an anterior or posterior cross-bite (Fig. 8, *E*). The dentist must differentiate between a cross-bite brought about by the relationship of the bones and a cross-bite

due only to the position of teeth. A crossed condition due to the arrangement of the teeth sometimes may be corrected and the teeth brought into proper alignment by incorporating full-coverage restorations. Developmental asymmetries of the jaws, however, contribute to an interarch cross that should not be "corrected" with restorations. Lateral excursions are usually impossible because of the locked occlusion. During the masticatory cycle the patient functions with a chopping, up-and-down

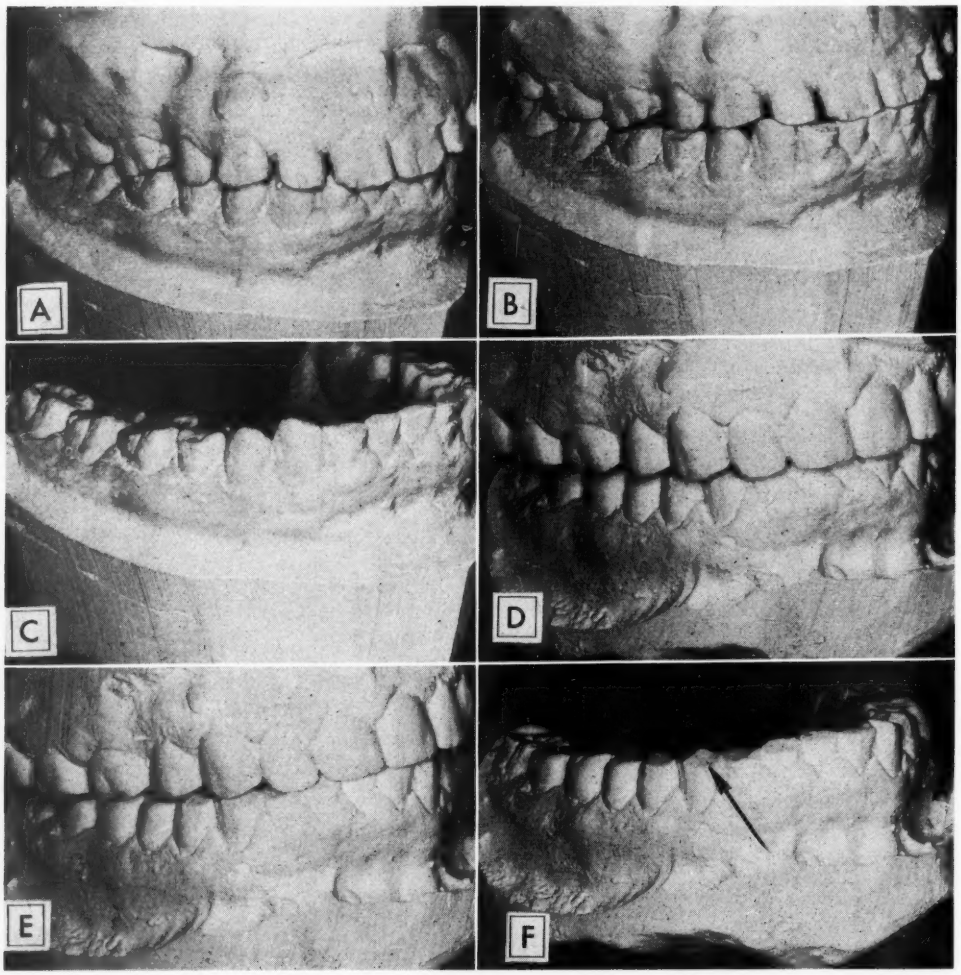

Fig. 10.—An occlusion influenced by abrasion due to bruxism. *A*, *B*, and *C*, Study casts of a young patient with the habit of bruxism, before rehabilitation. *D*, *E*, and *F*, Study casts made several years after treatment. Failure to recognize the habit of bruxism resulted in rehabilitation failure. After a few years, pain developed in the temporomandibular joints. Because the occlusal surfaces of the posterior restorations were in hard-cast gold, the movements of bruxism could not be satisfied. The six upper anterior porcelain-jacket crowns, however, did wear down the incisal edges of the mandibular incisors. The shorter they became, the more the patient had to force his mandible out of centric relation to make contact and satisfy the uncontrollable habit. As a result, the strained abnormal movements performed by the ligaments and muscles became painful.

motion. The neuromuscular system becomes accustomed to this pattern of mandibular motion, and the introduction of a new occlusal relationship is difficult and sometimes impossible. The cross relationship should be maintained when rehabilitating such a mouth.

Occlusion Treated Previously.—The ninth type of occlusion which may cause difficulty is the one that has just been treated a short time previously. Tact and understanding in the management of this type of patient are of prime importance, particularly because the patient has lost faith in dentistry. That faith will not be restored by belittling the work of the previous dentist. It is a good policy to consult the other dentist about the future management of the patient. If the patient is not cooperative, the dentist should not become involved. The management of the previously treated patient depends upon many factors, and it is not practical to offer any concrete recommendations. Cooperation and understanding should be prerequisites to retreating the patient. The treatment may never succeed and meet the demands of the patient.

Occlusion of Convenience.—The tenth situation unfavorable to occlusal rehabilitation is that of an abnormal occlusion of convenience. A patient may develop a convenient, functional pattern of chewing because of insufficient teeth or because of pain or discomfort due to interfering tooth contacts. This pattern of chewing often results in an abnormal occlusal relationship. Certain teeth are forced out of alignment, spaces develop between the teeth, and chewing surfaces become worn. Nevertheless, the patient is comfortable despite the abnormal actions of the facial muscles that occur during mastication. The dentist is cautioned about rehabilitating a mouth where the teeth function "conveniently." He may succeed in recreating a "correct" occlusal relationship, but such treatment does not always correct the habits of chewing and swallowing. Habits of long duration are not readily broken. A jutting chin, forced into that position by a functional habit, will often reassume its unsatisfactory position after the restorations are completed. Sometimes the habit will help fracture some restorations, force restored teeth out of alignment, or even loosen the restored teeth because they interfere with the comfort gained by the abnormal pattern of function. This risk should be explained to the patient before rehabilitation is started.

There are other occlusions that may be included in the same category as those preceding. Limitations do not apply to the functional relationship alone. Esthetic improvement frequently determines whether the rehabilitation is successful or not. What can and what cannot be improved esthetically depends upon the materials used and the conditions in and around the mouth. Recognition of the difficulties and explanation of them to the patient often prevent misunderstandings.

SUMMARY

Mathematics, engineering principles, precision, and uniformity of procedures must not dictate the physiology of occlusion. Failures in occlusal rehabilitation do not result from the use of, or the failure to use, a particular brand of instrument, a hinge-axis recording, or any other registration. Rather, they result from three basic errors. Unsuccessful results are often caused by increasing the vertical dimension of

occlusion beyond the limits of the physiologic rest position, by disregarding the limitations in and around the mouth, and by rehabilitating natural dentitions in *every* case along the lines and principles recommended for complete denture construction. A "balanced" occlusion in a natural dentition is a fallacy.

It is important to duplicate the functional curve of occlusion in patients who have the habit of bruxism. Ten unfavorable types of occlusion and their management should be understood by the dentist so that he will recognize the limitations of treatment and thereby avoid difficulty.

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OPERATIVE DENTISTRY

CONSERVATION OF THE DENTAL PULP—CAVITY PREPARATION

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THE PURPOSE of this article is to explain how basic principles can be used with new techniques and modern materials to provide better service for the patient. Basic principles are rules which guide the dentist when he operates. G. V. Black's *A Work on Operative Dentistry*[1] provides systematic techniques based upon careful study of fundamental principles. The anatomic uniformity of teeth and of carious lesions aided further simplification and systemization of Black's restorative procedures. These mechanistic advances, with their resultant conformity of instruction and practice, produced an "ideal cavity" concept that simplified teaching and acquisition of technical skill. This has not been without some disadvantages, however, especially for the patient.

Black[2] observed the tendencies toward oversimplification, standardization, and mechanization. He wrote, "In later years conditions have arisen which tend to mar the progress of the more scientific phases of thought in dentistry by diverting thought to the mechanical. . . . The result is that the more fundamental subjects are unable to command proper consideration and the mechanical parts are too often not well done. For this reason development in the scientific field is lagging behind." These words are as true today as when first written 50 years ago. The "ideal cavity preparations" which were classified, standardized, and systematized in the days of gold foil, amalgam, and foot engines are relatively unchanged in spite of the fact that dental materials and instruments have improved continuously. This situation creates a need for further study. The time has come when treatment for dental patients should be designed in accordance with basic principles of surgical procedures applied to the dental tissues, physical characteristics of modern materials and instruments, and the patient's need for dental health service. It is the aim of this article to discuss these requirements and to suggest how the dentist may use current biomechanical concepts and techniques to the advantage of all concerned.

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WHAT ARE BASIC PRINCIPLES?

Basic principles are the subject matter of basic sciences. They provide the framework on which clinical judgment is built. Analysis of patients' problems and application of basic principles to their solution are evidence of sound clinical judgment. Modification of ideal cavity preparations within the governing laws of fundamental principles is not a breach of faith with the time-honored system of Black, but an extension of his doctrines. Cavity preparations ideal in 1905 are not necessarily ideal in 1959. Black[3] said, ". . . every case must be treated on its own account, and demands consideration as to what the future may be. . . . It is only in recent years that we have known the cause of caries of the teeth; and therefore it is only now, we might almost say, that we are beginning to be able to apply effectively this knowledge to the prevention of recurrence of caries about our fillings. It is through this line of study and practice that the best progress of the immediate future is promised." It is evident from this statement that modification as dictated by biologic principles, mechanical factors, and sound clinical judgment is in accordance with his teachings. Unfortunately this aspect of operative dentistry does not lend itself readily to standardization or conformity. There are, nevertheless, certain guiding elements that are helpful.[4]

FACTORS GOVERNING CAVITY PREPARATION

The chief factors[5] that should be recognized, recorded, analyzed, interpreted, and considered in order to formulate a plan of surgical procedure for restoring teeth are (1) the patient, (2) the carious lesion, (3) the pulp, (4) the periodontium, (5) susceptibility of patient, tooth, and individual tooth surfaces to dental caries, (6) prevention of new carious lesions, (7) anatomy of enamel, dentin, and pulp chamber, (8) methods for excising tooth substance, and (9) materials used for restoration. All items listed require special, reflective consideration every time a patient is treated. Variations in any one may necessitate extensive modification of conventional, ideal cavity preparations.

FURTHER EXTENSION FOR PREVENTION

The operative dentist of today is confronted frequently with children and young adults whose teeth are almost wholly destroyed by dental caries. It is within this general area of practice, namely, treatment for patients with many carious lesions, that a combination of modern techniques and materials with modification of traditional operative procedures finds its most useful application.[6-15]

Modifications of Cavity Preparation.—Black's cavity preparations were tailored for gold foil or amalgam. These materials depend upon friction with parallel or undercut dentinal walls for their retentive stability and resistance to masticatory stress. When cast-gold inlays were inaugurated, they were fitted into cavity preparations patterned after the types used for foil and amalgam. In a few years, however, modifications were devised for gold castings which conserved tooth substance and guarded pulp health. The slice preparations of Willett[16,17] for deciduous teeth and those of Gillett[18] for the adult dentition are examples of this conservative tendency. Bronner's[19-22] modifications of cavity design for foil and cast gold were

also in accordance with sound fundamental principles and a conservative attitude. Boisson[23] showed why minimal excision of dentin was desirable and advocated the use of iridioplatinum staples for retention of castings. Kallenbach,[24] Campbell,[25] and Wylie[26] also contributed information which clearly indicated the need for changes in traditional cavity designs. Each of the foregoing authors made a substantial contribution to Black's[1] concepts of extension for prevention. These new systems, devised as scientific knowledge grew, were based upon studies of caries incidence, tooth anatomy, physiology, pathology, and biomechanics.

Modifications of Casting Placement.—The improvement of physical properties of gold for casting created a new way to conserve tooth substance. Restorative materials were used to strengthen the diseased tooth by placing the cast restoration around, rather than in, dentin. This development is exemplified today in veneers, overlays, onlays, three-quarter crowns, and other castings that attain the qualities of retention and resistance by encircling and resting upon tooth substance rather than by being anchored deeply within it.

Fig. 1.—A schematic representation of the uniformity of dentin thickness between the dentinoenamel junction and the pulp chamber. The basic principle depicted suggests that depth of cavity preparations be measured from the dentinoenamel junction and that this anatomic landmark be used as a guide whenever dentin is excised.

NEW METHODS FOR EXCISION OF TOOTH SUBSTANCE

Since the foregoing studies became a part of dental science, two major developments have taken place in dental teaching and practice. The first is the almost universal use of local anesthetics with vasoconstrictors during cavity preparation. This procedure, with its acknowledged hazards,[27-31] is a boon beyond price for both dentist and patient when it is really needed. The second is the advent of new

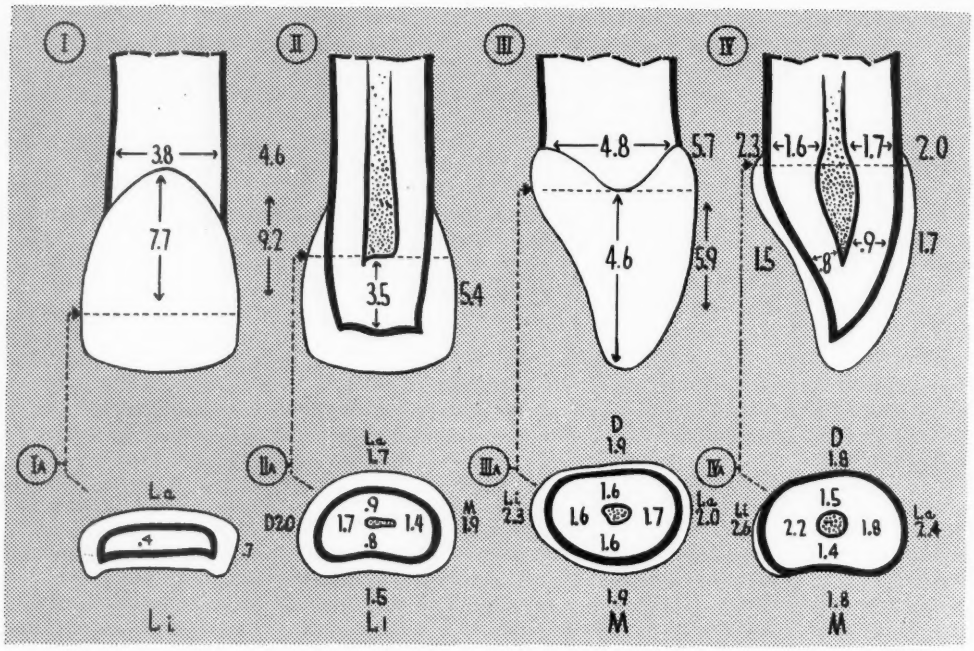

Fig. 2.—Dimensions of permanent maxillary lateral incisor (scale drawings—× 5). *D*, distal, *LA*, labial, *Li*, lingual, *M*, mesial. Numerals within teeth are the least distances ever found; numerals outside teeth are average distances for all teeth measured. *I*, Labial aspect, *IA*, Horizontal section through contact area; *II*, Mesiodistoaxial section, *IIA*, Horizontal section, tip of pulp horn; *III*, Mesial aspect, *IIIA*, Horizontal section, level of approximal cervical line; *IV*, Labiolinguoaxial section, *IVA*, Horizontal section, level of labial cervical line.

techniques for rapid excision of tooth substance. The modern dentist can avail himself of these advantages, to the eventual welfare of his patient, if he will plan his operation within the broad framework of biomechanical principles.

Dentin Volume—Dentinoenamel Junction.—There is a limited amount of dentin available for safe cutting in any tooth. As dentin is deposited rhythmically[32,33] there is a relatively constant amount around the pulp of each tooth. This biologic law has led to studies of dentin volume in relation to cavity preparation.[34-39] Fig. 1 illustrates the regularity of dentin volume and the limitations of depth of cut as a means of retention of restorative materials. The anatomic factors seen in Fig. 2 reveal the manner in which measurements are made from the dentinoenamel junction to the pulp. The dentinoenamel junction is a stable guideline from which the dentist can measure the depth of the preparation.

Fig. 3 shows how a safety zone[37] can be formulated for groups of teeth and systematizes this basic knowledge for all teeth. A safety zone is established with a dentin thickness of 0.5 mm. as an insulating barrier around the pulp chamber. The least amount of dentin measured in any tooth is used for this purpose. The data summarized in Fig. 3 are compiled from measurements made on hundreds of teeth of each type. Cavities prepared within the limits of the safety zones seldom cause pulp injury. By using the dentinoenamel junction as a guide to depth of cut, it is easy for the dentist to avoid the pulp.

Volume of dentin is important because one cannot cut dentin without cutting thousands of living cells of the dental pulp. Each odontoblast has a process extending from the cell through a tubule to the dentinoenamel junction. Excision with small burs of a minimal amount of dentin unaffected by the carious process produces little surgical trauma. Cutting in the carious or underlying sclerosed zone causes no pain and no serious pulp damage if little heat is produced.[40] This biologic principle is illustrated in Fig. 4.

Thermal Trauma.—Disadvantages of current techniques using large burs and stones at high speeds are partially offset by water-air coolants[41,42] or by air-abrasive[43] or ultrasonic[44] instruments. One may seriously question whether increased speeds justify the added hazards introduced into operative procedures.[45] Coolants (water, water-air mixture, air) do not always prevent heat production and pulp damage during cavity preparations.[46] There is only one sure way for a dentist to measure the traumatic effect of his technique and that is to cut into cavities in some of his patients' teeth without using local anesthetic.

Huet[47,48] pointed out in 1913 that it is necessary to know the sizes of rotating cutting instruments, as well as motor speeds, in order to compare the rates of travel of effective abrasive particles or blades in terms of linear feet per minute. Unless these data are given, the dentist has no precise knowledge of the conditions under which an experiment was performed, and he cannot reach a rational decision

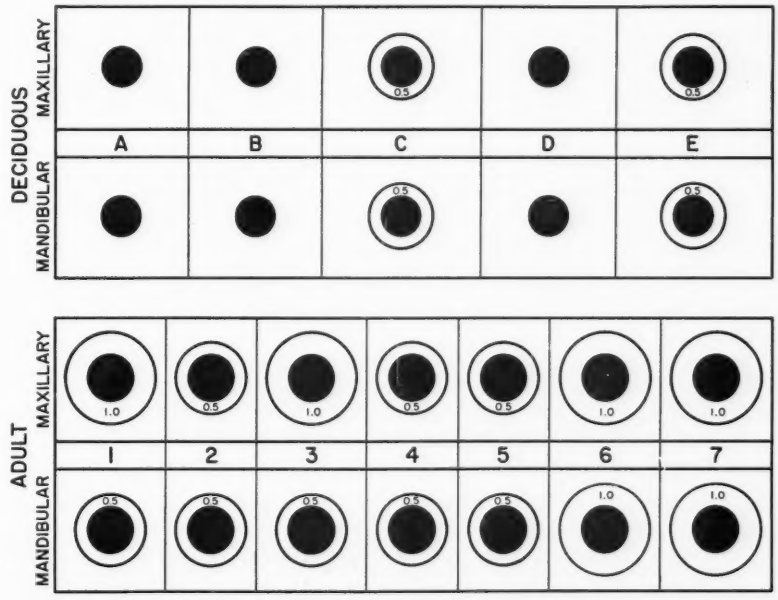

Fig. 3.—Safety zones. The depth to which dentin may be excised safely, measured from the dentinoenamel junction pulpally, is indicated in millimeters by the numerals within the circles. If the depth of a cavity preparation does not exceed the figure within the circle, there will always be at least 0.5 mm. of dentin between the cavity floor and pulpal wall. There is an exception to this rule on the lingual surface of the maxillary lateral incisor where as little as 0.8 mm. dentin has been found between the tip of the pulp horn and the dentinoenamel junction. The figures are based on the least amount of dentin ever found, not on the average.

concerning the validity of the results. Henschel[49] states, ". . . instrument surface speed of 5,000 feet per minute or more is required in vitro for maximum cutting efficiency. To reach this, a three-fourths inch disc must attain nearly 30,000 rpm. and a one-sixteenth inch diameter bur or stone about 300,000 rpm."

Huet's[47] research demonstrated the value of three important principles. The first was that different speeds are advisable for dentin than for enamel. The second was that reactions of patients operated upon without an anesthetic guided the dentist in improving his surgical skill. The third was that short periods of intermittent grinding minimize excessive heat production. Huet found that burring with a pressure of 500 Gm. for two-fifths of a second and resting for three-fifths did not hurt his patients. All these observations support the concept that operations causing no pain to the nonanesthetized patient seldom, if ever, result in serious trauma to the dental pulp.

Clinical Test for Pulpal Trauma.—Pulpal tissue is traumatized if its temperature is raised as much as 10°F. It may be seriously damaged with further increases[50-54]; consequently, the operative dentist needs a delicate, accurate scientific instrument with which he can measure traumatogenic qualities of his own surgical techniques, thermal and otherwise. There is no scientific apparatus or laboratory experiment as good for this purpose as a nonanesthetized patient. Potentiometers, oscilloscopes, microscopes, or anesthetized monkeys cannot tell the dentist that the tooth hurts because it is hot. Patients can and will do so when a nonanesthetized living tooth is drilled on too long or with too much pressure. It is recommended that every dentist prepare a few cavities each day without anesthetic in order to develop safer, gentler, and quieter drilling techniques.

FUNDAMENTAL BIOMECHANICAL CONCEPTS AND MODERN TECHNIQUES APPLIED CLINICALLY

In the foregoing discussion the point has been made that certain modifications of the ideal cavity concept and of the techniques for its preparation are desirable. A specific example will be given now to show how the dentist may plan and perform an operation using both basic principles and modern techniques. The biochemical concepts used as guides to correct surgical techniques are logical derivations of the best thought of the past, coupled with the improvements available in the methods and materials of today.

The Patient.—The dental-health needs of the patient are the chief concern of the dentist. "Every case must be treated on its own account. . . ."[3] The patient in the following discussion was a young lady, 24 years of age, in excellent general health, prettier than average, who had a high incidence of active carious lesions and well-established gingivitis of several years' duration. Although she brushed her teeth regularly and followed directions given by her dentist, she was aware that the cavities in her teeth were continuing to increase in size and number and noticed that her gums were tender. She wanted something done for cavities in the upper left lateral incisor as soon as possible because they were unattractive.

The Carious Lesions.—The mesial carious lesion, as revealed roentgenographically and by transillumination, extended labiolingually from the middle through

the lingual third of the proximal surface. Incisogingivally, the lesion occupied the area from just below the contact zone in the middle third to the actual contact area in the incisal third. It spread 1 to 2 mm. in all directions along the dentino-enamel junction and penetrated along the dentinal tubules about two-thirds of the distance to the dental pulp. The distal lesion was a little higher on the tooth and slightly smaller.

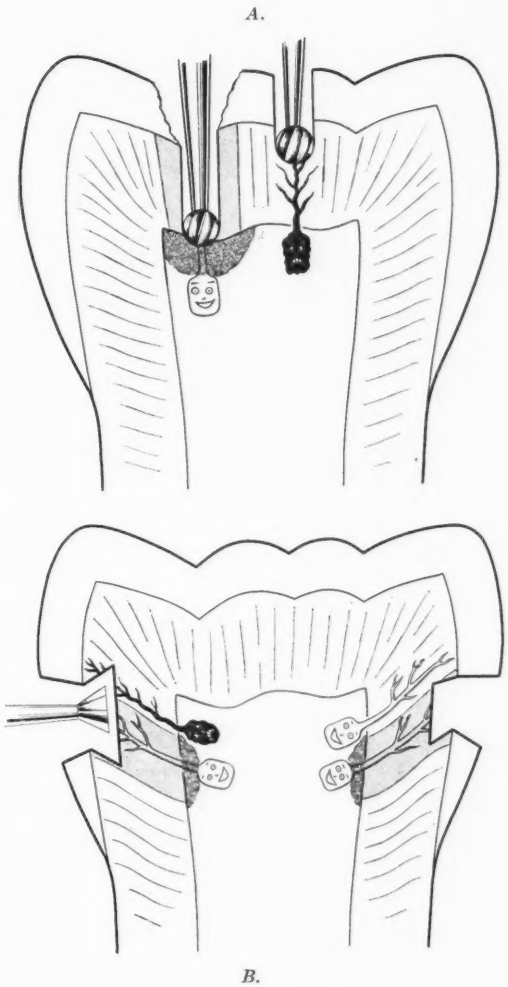

Fig. 4.—*A*, Schematic drawing showing that drilling in carious or underlying sclerotic dentin causes no pulpal response, while excision of unaffected dentin may cause pain. *B*, Clinical application of principle depicted in Fig. 4, *A*. When Class V cavity preparations are excised within the sclerotic zone, painful responses are minimized. Excision beyond the sclerosed area leads to increase in painful responses.

The Pulp.—The dental pulp responded to heat, cold, and electrical tests. The tooth color was good and there was no evidence of hypersensitivity. Roentgenographically, no evidence of change in pulp form or density was observed.

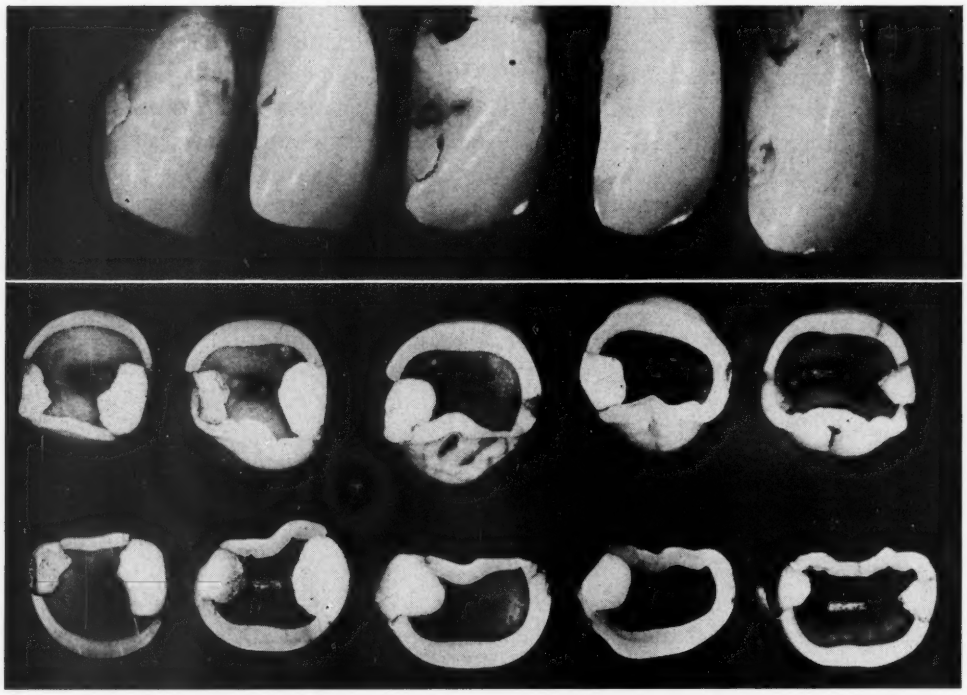

Fig. 5.—Lateral incisors with silicate restorations chosen as typical examples of routine operations in dental schools and private practice. The second and third rows show the teeth sectioned through the restorations and contact zones. Dentin is stained with acid fuchsin. The apical portion is in the top row and the incisal tip in the bottom row. Note that carious lesions or restorations are found on all approximal surfaces.

The Periodontium.—The periodontal tissues revealed no evidence of change roentgenographically, and the tooth was not mobile. The gingiva was slightly reddened, flabby, and ulcerated. The gingival crest was 2 mm. incisal to the cervical line and almost reached the contact zones on the approximal surfaces.

Susceptibility of Tooth Surfaces to Dental Caries.—When the microorganisms were stained on the tooth surfaces with basic fuchsin disclosing solution,[55] their distribution and volume, revealed by the dye, demonstrated a need for effective, personal oral hygiene. The disclosing solution showed the chief cause of the high incidence of lesions throughout the mouth to be associated with the bacteria.

Prevention of New Carious Lesions.—The self-cleansing surfaces at the line angles were free of microbial material or signs of carious demineralization. This suggested that labial extension of the restorations could be held to a minimum.

Anatomy.—The tooth was tapering in form and in proper position in the dental arch. It was slightly smaller than the average and thin labiolingually in the incisal two-thirds. These conditions posed a serious problem because this is one tooth that has very little dentin (Fig. 3). In addition, the lingual tip of the pulpal horn may be unusually close to the dentinoenamel junction (Fig. 2).

Methods for Excision of Tooth Substance.—Current methods for excision using high-speed instruments, water sprays, and diamond points significantly reduce the time required for cavity preparation. This is an important consideration to the

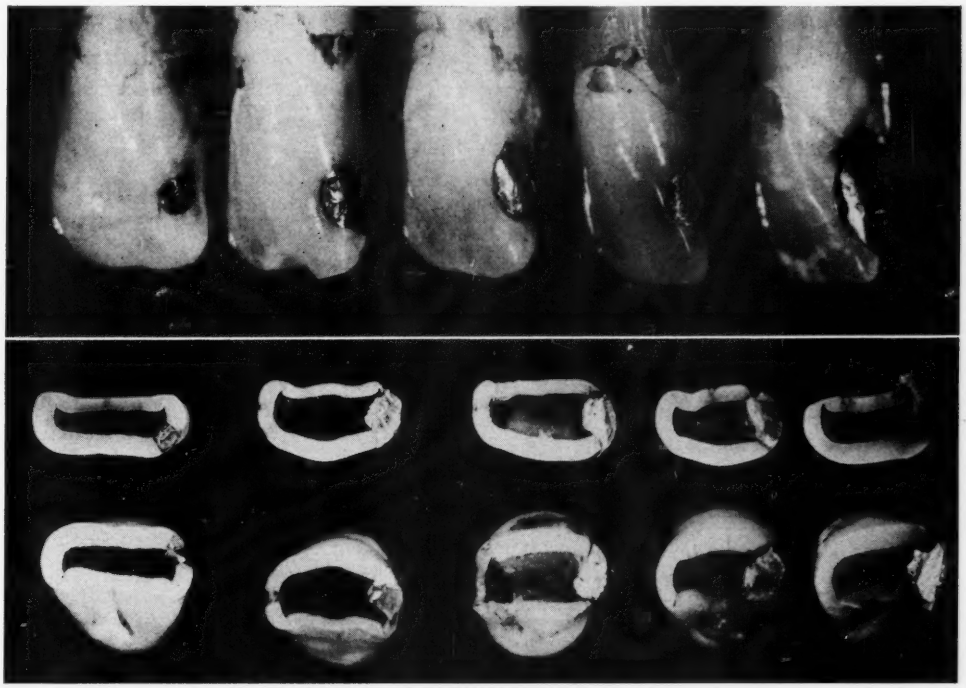

Fig. 6.—Lateral incisors with gold-foil restorations chosen as representative examples of routine operations in private practice and dental schools. Foil restorations varied greatly in size. The teeth are sectioned through the foil and the contact zone. The incisal tip is in the middle row. Note that only two teeth have approximal surfaces unaffected by dental caries. Dentin is stained with acid fuchsin.

patient, as well as to the dentist. These instruments are too big, however, to prepare a cavity safely within the scanty dentin of this particular tooth. They are ideal for preparing the tooth for a three-quarter crown. The choice of instruments used and the techniques of excision, therefore, depend partly on the restorative material employed.

Restorative Material.—The choice of restoration for the lateral incisor of the patient was relatively simple. A silicate restoration was undesirable because of the depth of the lesion mesially, the lack of favorable physical properties of the material, and the known injurious effects of silicate on the dental pulp.[56,57] Also, retention for silicate must be within dentin. Even though a preparation is held within the boundaries of the carious lesion, enamel is usually undermined and the restoration does not add to the final strength of remaining tooth substance. With passage of time, silicate will wash out and discolor along the margin. An acrylic-resin restoration was not recommended for similar reasons.

A series of teeth containing silicate fillings made by reputable dentists under routine practice conditions is shown in Fig. 5. These teeth were selected as representative of thousands that have been dissected as shown and examined. Each served satisfactorily for several years. The transverse sections show undermined enamel, excessive excision of dentin, and pulp exposure. There are wide differences between doctrine and practice.

A gold-foil or gold inlay was even more undesirable than silicate for the patient in this discussion. The many problems associated with such restorations are revealed in Figs. 6 and 7. The examples were chosen from a large number of specimens. They are typical samples and give a good idea of the paradoxical disparity between theory and practice.

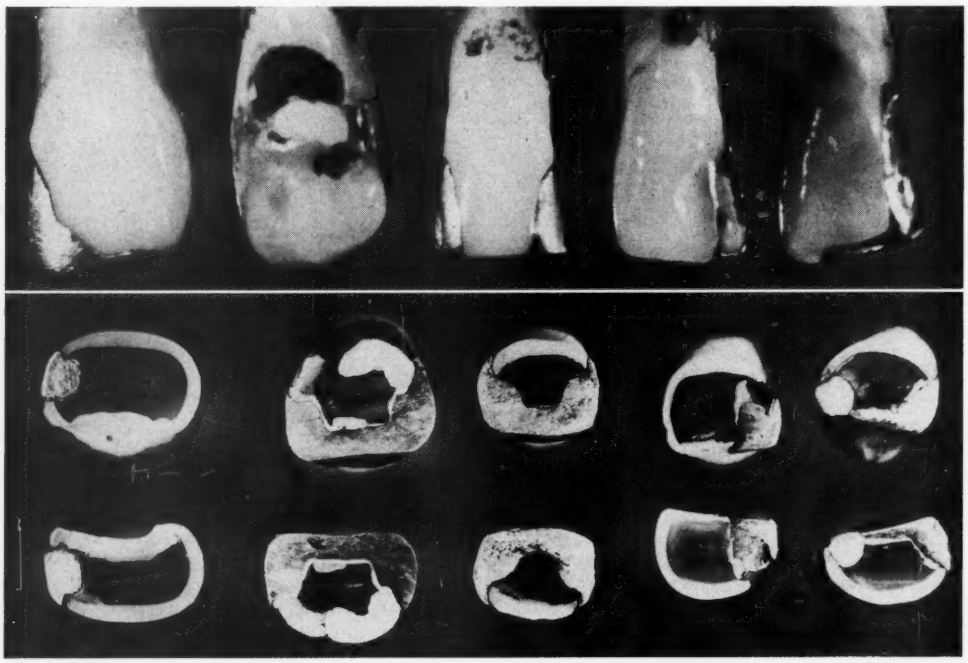

Fig. 7.—Incisors restored with gold inlays chosen as representative examples of routine operations in private practice and in dental schools. The teeth are sectioned through the restoration and contact zones and the dentin is stained with acid fuchsin. The incisal tips are in the bottom row.

The anatomic characteristics of the lateral incisor with the presence of lesions on mesial and distal surfaces suggest an encircling design with extracoronal retention for the restoration, rather than the deep, radical excisions required for silicate, foil, or inlay. The three-quarter crown best fits the fundamental biologic factors under consideration, as well as the use of modern techniques and materials. It has been generally accepted as the restoration of choice when an abutment is needed for a bridge. It is even more satisfactory as a unit restoration. It strengthens the tooth with minimal excision of healthy dentin and enamel. Little, if any, gold need show on the labial surface when the impression is withdrawn linguoincisally and an excellent esthetic result may be obtained.

Fig. 8 shows teeth with this type of restoration. The conservation of pulpal tissue and surrounding dentin is well illustrated. The restorations served satisfactorily for many years. Those illustrated were chosen as characteristic from a large collection. Their quality indicates the ease with which a casting of this type

can be placed, and study of the extracted teeth reveals how well they last. Since all the examples had cavity preparations that allowed withdrawal of the impression in an incisal direction only, more gold shows on the labial surface than is necessary.

Fig. 9 shows an extracted upper lateral incisor treated in accordance with fundamental principles and modern techniques applicable in the case under consideration. The picture is intended to serve as an example of the type of treatment recommended for the patient. It was illuminated from behind so that the restoration can be seen. With modern impression materials, cutting instruments, and casting gold, this operation is easy to perform in the dentist's office. It provides an improvement in the quality of professional service as well as in the efficiency of the operator.

Further Extension for Prevention.—Regardless of the type of restoration the patient and dentist choose for this tooth, her dental health problem will not be solved until she is taught how to prevent and control dental caries and periodontal disease. Steady increases in the incidence of dental caries and periodontal disease are the order of the day. Unless the dentist recognizes his obligation to teach the patient effective, personal oral hygiene, his finest restorations will soon be worthless. Techniques for this purpose are described in other publications.[11-15,55]

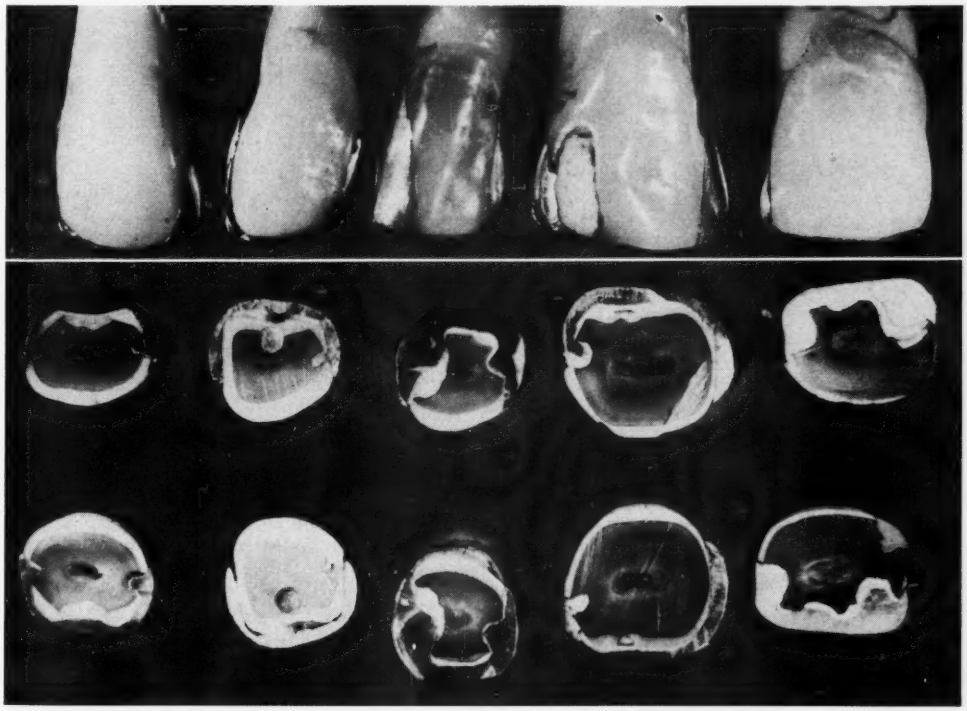

Fig. 8.—Incisors restored with three-quarter crowns chosen as representative examples of routine operations in private practice and in dental schools. The teeth are sectioned through the restoration and contact zones and the dentin is stained with acid fuchsin. The incisal tips are in the middle row. Note that the pulp chambers are filled with secondary dentin when the deep carious lesions were filled with cement bases. This is also true of the second tooth from the left where a pin was inadvertently placed near the pulp.

FAILURES TO ACCOMPLISH PULP CONSERVATION

The thoughts concerning operative procedures expressed in this article were long in coming. The reader may ask why modification of the ideal cavity preparation is ever necessary; he "never had a failure." His viewpoint is understandable. The pulp may not die until many years after an operation has been performed. Patients may go elsewhere, as they often do. Seldom a week passes, however, without one or more coming to the attention of our Department of Pathology. Three of these cases are illustrated in Figs. 10, 11, and 12.

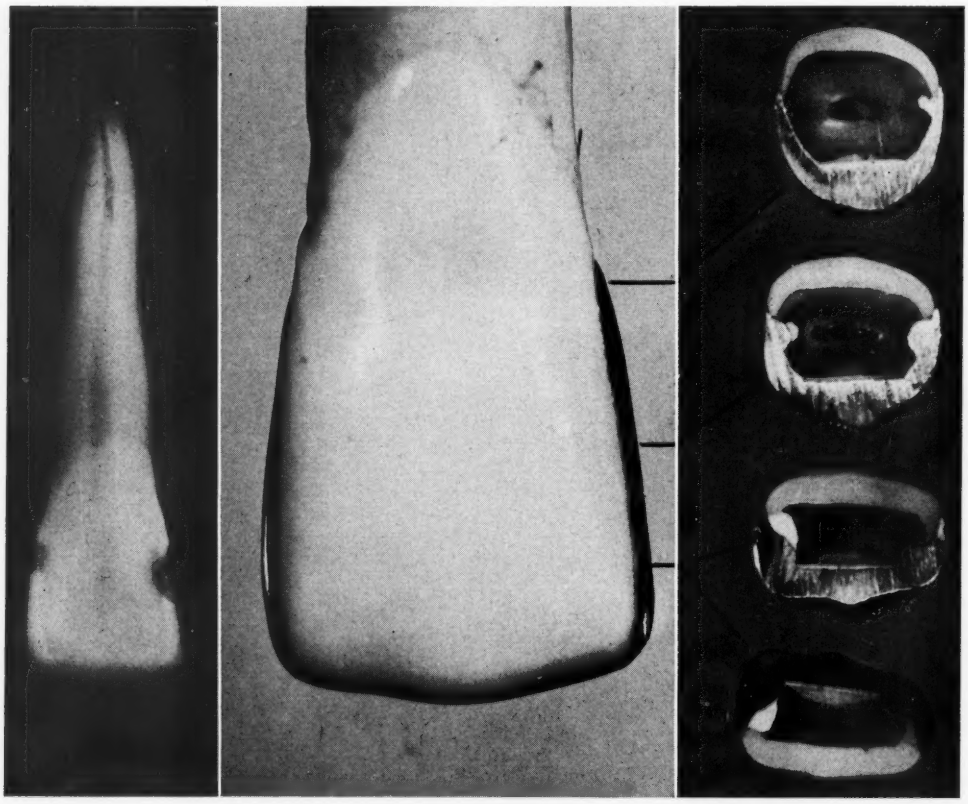

Fig. 9.—A roentgenogram, a photograph, and sections of an extracted carious lateral incisor restored with a three-quarter crown. The preparation was designed to allow withdrawal of the impression linguoincisally, thereby conserving the esthetic qualities of the labial surface. This tooth is shown as an example of recommended procedure. Note the deepest carious lesion is partly filled with a cement base.

The first terminated 5 years after the lateral incisor had been prepared for and filled with silicate, with a local anesthetic but no insulating base used in the preparation (Fig. 10). This patient also lost four other teeth, none with pulp exposure, but all at varying intervals from the time they were operated upon. It is thought that they are good examples of anachoretic pulpitis[58,59] following surgical trauma, created by injudicious use of anesthetic, deep excision of living dentin, excessive heat during cavity preparation, injurious drugs, and irritating restorative materials.

The second mishap occurred in the mouth of a young surgical resident. An inlay was made for his upper left first molar. Five months later he developed a streptococcal sore throat and was hospitalized. Positive blood cultures of *Streptococcus hemolyticus* were obtained. He was treated with penicillin and recovered in a few days, but one week later he had a headache on the left side that localized with swelling at the apex of the lingual root of the upper first molar. A fistula appeared at this site within a week and a needle inserted into the opening penetrated readily to the apex (Fig. 11, *B*).

The inlay had been worn by the patient for 5 months before symptoms of pulp damage arose. When the cavity was prepared, the tooth was anesthetized at each appointment. Six appointments were required. All excision of tooth substance was

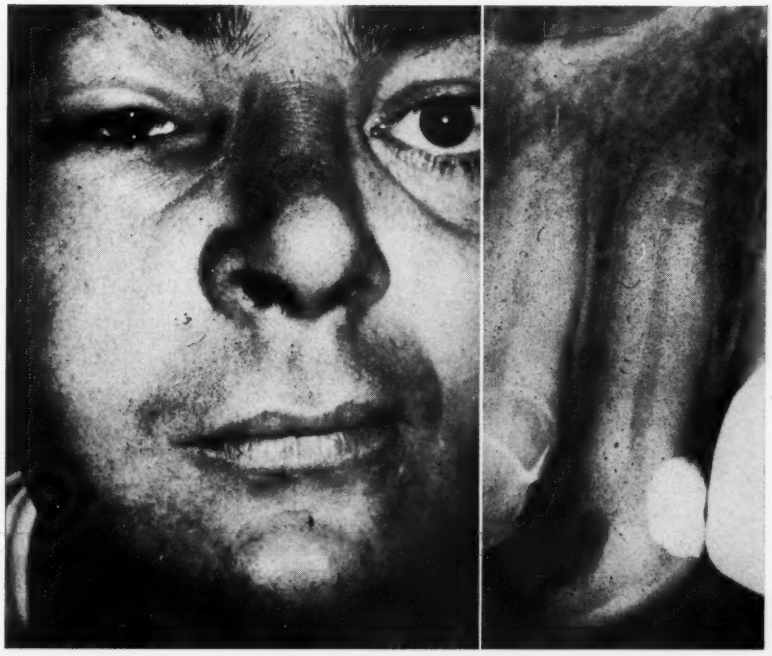

Fig. 10.—A patient with cellulitis of the face and pulpitis in the maxillary lateral incisor 5 years following restoration with silicate cement. No pulp exposure was found in the extracted tooth but the restorations were within 0.5 mm. of the pulp chamber. The pulp was necrotic.

done under a stream of water. Phenol was used to wipe the cavity each time a temporary stopping was placed. Appointments were at weekly intervals. Just before the inlay was seated, the cavity was phenolized and flooded with silver nitrate, which was then precipitated with eugenol. Oxyphosphate of zinc cement was used to seat the inlay. The patient had a severe throbbing toothache that gradually subsided through the night. The tooth remained excessively sensitive to heat and cold for months.

The pulp responded to heat, cold, and electrical tests just prior to extraction, 5 months and 2 weeks after the inlay was cemented in the tooth. The tooth (Fig. 11, *A*) was cracked open and the inlay removed. It weighed 50 grains. There was

Fig. 11.—*A*, Split tooth showing the cavity preparation within 0.5 mm. of the pulpal horn. The dentin is stained with silver nitrate applied during operation. *B*, A roentgenogram of a tooth with a needle in a fistula from the lingual root. *C*, A photomicrograph of pulp from the lingual root. Tissue is avascular and cloudy, and a few mononuclear leukocytes are present. *D*, A photomicrograph of fibrosed and diffusely calcified pulpal tissue from the apical tip of the lingual root. Note the scarcity of cellular elements and relative avascularity of tissue.

no evidence of pulp exposure. The cavity preparation was 0.5 mm. from the dental pulp at the closest point. The pulp tissue was soft, cloudy, and easily torn except in the lingual root where it was dense, opaque, white, and hard. Microscopic examination revealed cloudy swelling, necrosis, and polymorphonuclear exudation in the coronal portion. The apical part in the lingual root (Fig. 11, *C* and *D*) was fibrosed, diffusely calcified, and avascular. Because no pulp exposure was found, this appears to be another case of anachoretic pulpitis.

A young lady provided data for a third case. A Class III, gold-foil restoration was placed in the upper lateral incisor. A local anesthetic was used, separation was obtained, too much dentin was excised, the pulp gradually died, and a fistula formed within a period of 3 years and 4 months following the operation (Figs. 12*A*, 12*B*, and 12, *C*). Had this tooth been treated in accordance with biomechanical principles the operation would have been successful. Fig. 12, *D* is made from serial sections through the three-quarter crown seen in Fig. 9 and from the sectioned foil shown in Figs. 12*A*, 12*B*, and 12, *C*. The biomechanical advantages of modern techniques and materials are shown. The three-quarter crown conserves and strengthens tooth substance while providing pulp protection.

Fig. 12*A*.—A lateral incisor which had been restored with gold foil 3 years previously, with a fistula over the apex.

DISCUSSION

Failures.—The failures described in the preceding paragraphs are typical. If one can judge by the number on file in the pathology laboratory, they must be occurring by thousands throughout the nation. Those chosen came from the east, midwest, and southwest areas. From study of the cases on file, the factors which most often lead to pulp death can be listed under the following general headings: (1) unplanned, hasty, injudicious excision of living dentin, (2) thermal changes (heat and cold) affecting dental pulps during and after operation, (3) drugs—anesthetics and sterilizing agents, and (4) restorative materials—silicate cement, copper cement, and gold foil.

The customary practice of using local anesthetic for cavity preparation on all patients contributes, more than any other single factor, to a careless disregard of basic principles. The gold-foil operation described above was performed in practice

for a state board examination. Since the pathologic changes in the dental pulp were not manifested during the examination, the student passed with an excellent grade. Errors in clinical judgment of this kind are common wherever Class III gold foils are required for student graduation and licensure. They are not always an indication of lack of surgical skill on the part of an operator or lack of professional judgment on the part of the examiner, but the eventual misfortunes are direct evidence of a thoughtless disregard, by all concerned, for basic principles.

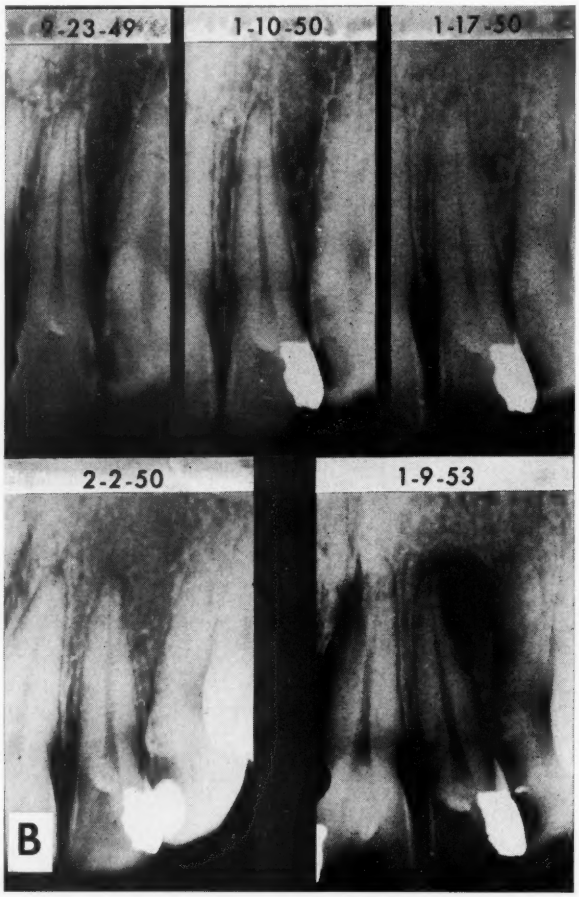

Fig. 12*B*.—Roentgenograms of the tooth before and after the operation.

As one sees many cases similar to that just described and realizes that most of these operations are performed on patients in order to evaluate digital skills, he wonders if a cavity preparation in a nonanesthetized vital tooth might not be a better test of the operator's professional abilities. If an anesthetic must be used, would not the choice of a tooth with maximal dentin volume reflect a better understanding of fundamental principles? Then, most important of all, is not any test of professional prowess which includes an operation that is not in complete accordance with the

patient's general welfare an obvious manifestation of the examiner's disregard of the basic principles Black[2] valued so highly?

Because so few students develop the necessary surgical skills for successful manipulation of this material in the crowded curriculum of dental education today, would it not be an improvement to teach this discipline at the postgraduate and study club level? How many more incisor teeth must be sacrificed on the altar of gold foil and digital skill before all state board examiners discontinue the Class III requirement?

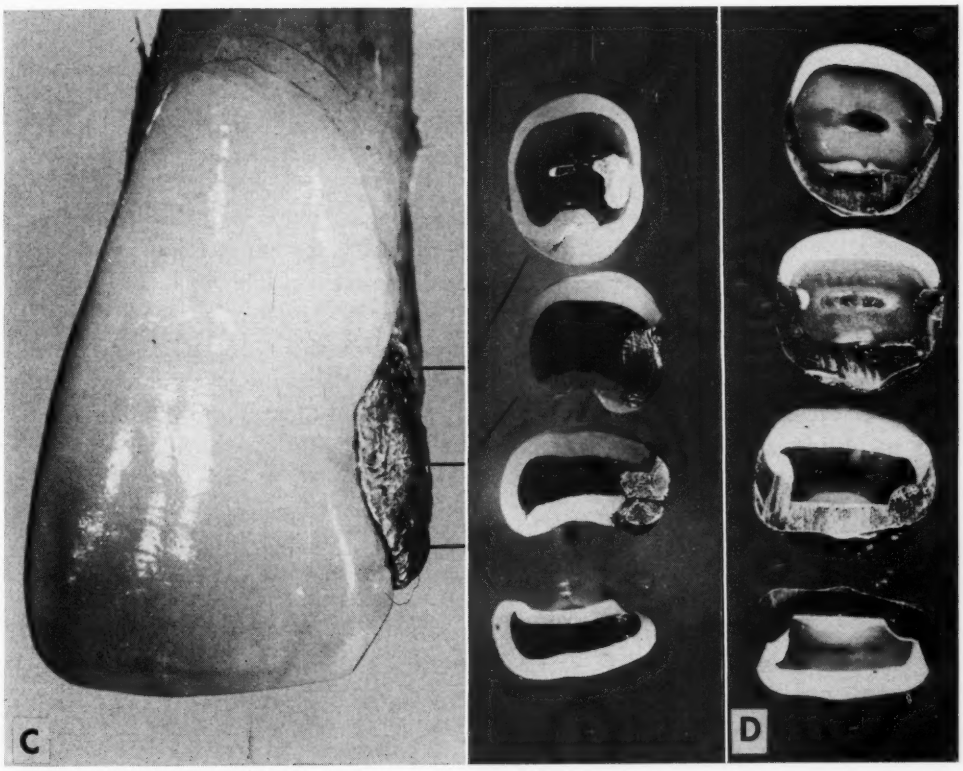

Fig. 12.—*C*, The extracted tooth and sections cut at the levels indicated. *D*, Comparable sections from a lateral incisor restored with a three-quarter crown.

Recommended Procedures.—If it is necessary to perform these operations in incisor teeth, the dentist should apply his basic knowledge by choosing a thick, ovoid tooth which is securely embedded in the jaw and has a single, tiny lesion located as far gingivally as can be found. The operation should be performed without local anesthetic, and extension for retention and prevention should be precise and limited.

Teeth operated upon skillfully are usually painless during and after cavity preparation. Prior to the advent of local anesthetics, dentists won their reputations as excellent operators with their ability to prepare cavities with little or no pain. Evidence that these skills are not wholly lost and that they are practical with modern instruments and techniques is presented by Herzberg.[60,61] He describes patient reactions while he prepared 2,352 cavities without local anesthetic.

The skillful surgeon plans his operation with great care, he analyzes all possibilities carefully using basic principles for guidance, then he performs the operation to the best of his ability and to the best advantage for his patient. It is recommended that the conscientious dentist seriously concerned with pulp conservation plan each operation carefully and prepare some cavities without anesthetic each day. In addition, he should evaluate the results of his operative procedures by splitting, sectioning, and studying previously filled teeth whenever this is feasible. Interesting teeth should be placed in 10 per cent formalin and sent to an oral pathologist for consultation.

SUMMARY

The thoughts in this article may be summarized by stating that patients with dental caries are afflicted by a serious ailment. Their teeth are diseased and have carious lesions within them. When a carious lesion is excised, living tissues are cut. Excision of viable dentin is excision of extended living pulp. In order to treat patients with diseased teeth successfully, sound clinical judgment is required in addition to surgical skill. Sound clinical judgment dictates a sensible combination of old and new therapeutic practices for the patient's benefit. The dentist wants each patient to have the best treatment he can provide. The patient receives such treatment when the operation is carefully planned and executed within the broad framework of basic biomechanical principles from which all successful therapy derives. An operation so planned and conducted conserves the dental pulp, promotes patient welfare, and enhances the dentist's professional reputation.

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TECHNICAL PROCEDURE OF PRECISION CASTING

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FACTORS GOVERNING PRECISION CASTINGS were investigated and reported previously.[1,2] A clinical procedure for precision castings has been developed from the data obtained, and the important points of this system will be discussed.

DIMENSIONAL CHANGES OF CASTINGS

Although an investment having a 2.0 per cent (0.2 per cent setting and 1.8 per cent thermal) expansion has been experimentally developed,[2] the expansion of most present-day, commercially available cristobalite investments* is about 1.6 per cent in the technique eliminating hygroscopic effect. With such an investment expansion, a comparatively great expansion of indirect models is desired to compensate for casting shrinkage of gold alloy to fit external inlays.[2]

Complex or external inlays should be made by indirect method, while simple or internal inlays can be made by either direct or indirect method. The net dimensional changes, in per cent, of casting restorations are shown in Table I. Most of the factors of dimensional change recorded in this table were determined in the previously reported works.[1,2] The net changes of the three techniques to be described lie in the ranges of desired change with a constant investing material and technique regardless of the possible variation of room temperature from 10° to 35° C. (50° to 95° F.).

ALGINATE INDIRECT TECHNIQUE

The most economical, simple, and accurate indirect method is the alginate indirect technique. The following six factors for obtaining accurate die surfaces are important particularly for this alginate technique:

1. A selected impression material should be used, since the surface accuracy of models is remarkably different with various brands of alginate.[3]

2. The alginate impression material should be spatulated thoroughly in the limited time of one minute.

3. A fixation of impressions in a 1.0 to 2.0 per cent $ZnSO_4$ solution for 30 seconds is adequate for all alginate impression materials tested.[3] This is essential even if the manufacturer does not recommend fixing.[3]

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*Examples: Ransom & Randolph's Cristo-Pak, Kerr's cristobalite investment, Shofu's cristobalite investment, etc.

TABLE I. CALCULATION OF DIMENSIONAL CHANGES OF CASTING RESTORATIONS (%)

TYPES OF RESTORATIONS		EXTERNAL INLAYS	INTERNAL INLAYS	
TECHNIQUE FOR MAKING WAX PATTERNS		ALGINATE-HYDROCAL INDIRECT	DIRECT FROM MOUTH	ALGINATE-HYDROCAL INDIRECT
Expansion of working dies	A	+0.5	—	+0.3
Wax change in mold	B	0	−0.2	−0.2
Wax change after removal	C	0	0~−0.5	0
Total investment expansion	D	+1.6	+1.6	+1.6
Casting shrinkage	E	−1.9~2.0	−2.1	−2.1
Net change A+B+C+D+E=F		+0.1~0.2	−0.7~1.2	−0.4
Range of desired change		+0.1~0.5	−0.3~1.2	−0.3~1.2

A: Working dies made pouring Plastone (Hydrocal) in Technicol (alginate) impressions.
B: Wax shrinkage from mold wall.
C: Cooling shrinkage of wax from mouth to room temperature (10°~35°C).
D: Shofu cristobalite investment used with dry asbestos lining covered with petroleum jelly.
E: Casting shrinkage of medium or hard inlay gold alloy.

4. Before the cast is poured, the excess fixing solution should be removed from the impression, leaving a film of solution on the impression surfaces.[3] A light shake of the impression is adequate for this purpose.

5. A Hydrocal-type of stone should be used, because Densite-type stones produce rough die surfaces in alginate impressions.[3] A nearly pure Hydrocal produces better surfaces in alginate impressions than a Hydrocal containing more chemicals for the control of setting expansion.

6. The stone cast should not be taken out of the impression for at least one hour after pouring. Earlier removal produces a rough and soft die surface.[4]

Using these precautions, we obtained excellent die surfaces by pouring Plastone* in Technicol† impressions. These materials reproduce a fine line up to 10μ in tests (this accuracy is equal to that with rubber-base impressions).

The distortion of alginate impressions manipulated correctly is smaller than that of rubber-base impressions when made at mouth temperature and poured at room temperature.[5] To obtain indirect models having minimal distortion and adequate expansion, the following six precautions are essential with alginate impressions:

1. The handle of the partial impression tray should be loose.[6] With a tight tray handle, movement of the lips will distort the setting impression.

2. All object teeth should be completely covered by tray walls, to prevent the unsupported portion of the elastic impression from becoming distorted.

3. An elastic resistance should not be felt when the impression is placed in the mouth since the elastic compression of setting colloid produces serious stress. Alginate should be mixed with ice water in hot weather to lengthen the gelation time.[6,7,8]

*Hydrocal, The G. C. Company of Japan.
†An irreversible hydrocolloid, The G. C. Company.

4. Remove the impression by a single, sudden motion 2 minutes after the apparent set.[6,7]

5. The impression should be fixed immediately after removal and the stone mixed during the fixation for 30 seconds, to minimize the interval between removal and pouring.[5,6]

6. A Hydrocal of high expansion should be used[5] and the impression poured upon a vibrator set at a mild rate.[7]

For purposes of simplification I devised a syringe, a tray, and an articulator for use with the alginate indirect technique to make inlays, crowns, and fixed partial dentures (Fig. 1).[6]

To save time, a paraffin-wax interocclusal record is made while the gingival margin is displaced by a cotton thread containing $ZnCl_2$ crystals. Then, an alginate impression is made of the prepared teeth with the use of the syringe and the tray. Thus, only two impressions are needed throughout the whole procedure, even for fixed partial dentures.

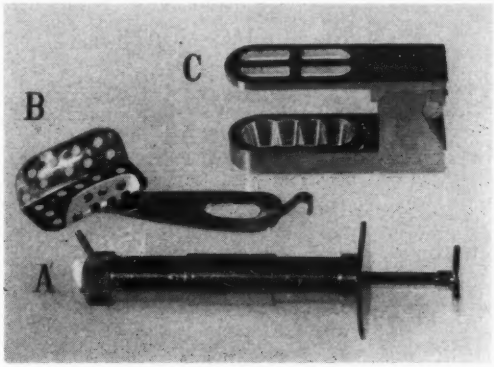

Fig. 1.—The armamentarium used for the alginate indirect impression technique: *A*, the syringe; *B*, the tray; and *C*, the articulator (From Fusayama: J.A.D.A. 54:74, 1957.)

The mixing of the artificial stone is started immediately after the alginate impression is removed from the mouth and immersed in a fixing solution. The stone mix is poured in the alginate impression, and the larger part of the articulator is placed upon the stone (Fig. 2). Thereby, the cast is mounted on the articulator one minute after removal of the impression from the mouth.

The paraffin interocclusal record is fixed upon the cast of the prepared teeth (Fig. 3), and another mix of stone is poured. Then the smaller part of the articulator is placed in position and attached to the stone. The entire working cast is completed with two mixes of stone.

An inlay, crown, or fixed partial denture can be completed on this working cast by a one-piece casting (Fig. 4).

PRESS-MOLDING OF WAX PATTERNS

Softened wax should be press-molded, and the use of molten wax should be minimal.[1] A stainless-steel, ready-made matrix is used in the mouth for press-mold-

ing of the wax pattern, and a celluloid strip is used on the die as a matrix. Regular inlay wax is used in the direct method, while baseplate paraffin wax (hard) is preferred on indirect models except in very warm weather.[1]

The press-molding of wax on a full crown preparation is facilitated greatly by the use of a copper band and a clip or holder (Fig. 5). A thin copper band of 0.1 mm. thickness is cut into a strip, annealed, and bent into a loop. The band surrounds the preparation with a space of approximately 1.0 mm. all around it. Both ends of the band are held together by the holder, and petroleum jelly or cocoa butter is coated inside the loop. A piece of paraffin wax is softened, filled in the loop, and pressed upon the preparation with a finger (Fig. 6).

Fig. 2.

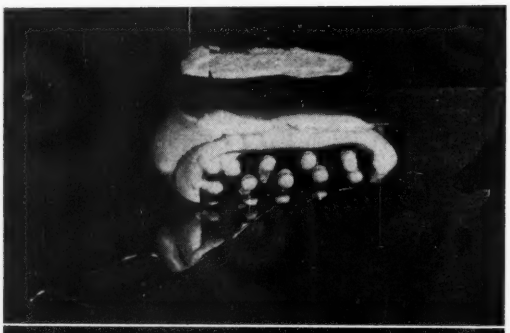

Fig. 3.

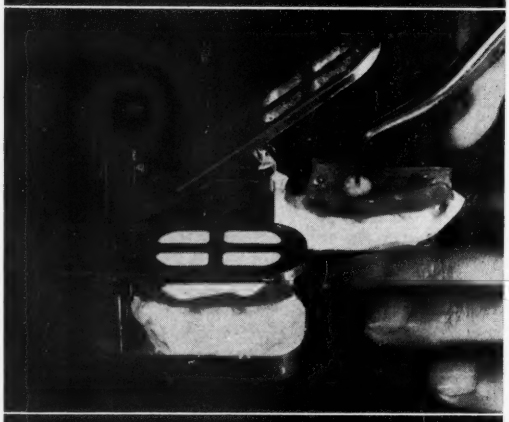

Fig. 4.

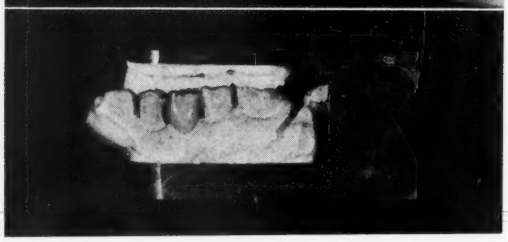

Fig. 2.—The articulator is placed directly upon the stone mix in the alginate impression. (From Fusayama: J.A.D.A. 54:75, 1957.)

Fig. 3.—The wax interocclusal record is placed upon the cast, and stone is poured into it. (From Fusayama: J.A.D.A. 54:76, 1957.)

Fig. 4.—A one-piece cast fixed partial denture is completed on an alginate-Hydrocal indirect cast.

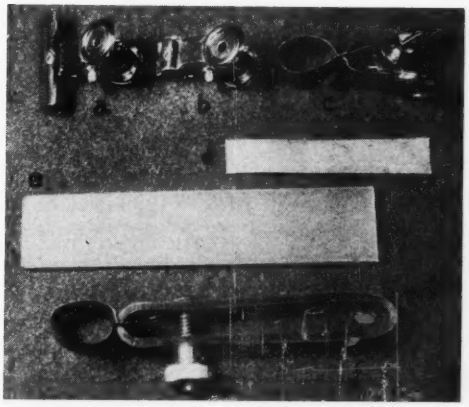

Fig. 5.—Equipment for press-molding a crown wax pattern. The clip *(a)* is altered in shape *(b)* and used as a band holder *(c)*. A recently devised, ready-made band holder *(f)* is more convenient. A thin copper band of 0.1 mm. thickness is cut into a strip *(d)* from a copper sheet *(e)*.

Fig. 6.

Fig. 7.

Fig. 6.—Press-molding of a crown wax pattern on an indirect die.

Fig. 7.—Trimming of a press-molded crown wax pattern. *a*, The copper band is removed, *b*, exposing the wax. *c*, The wax is carved.

After cooling thoroughly, the band is removed. The press-molded wax left on the preparation is carved into an anatomic and functional form (Fig. 7).

A one-piece cast fixed partial denture is waxed as seen in Fig. 8. Both abutment wax patterns are prepared by the press-molding method. They are removed once to insure removability and placed back in position.

The occlusal surface of the pontic is carved using a ready-made acrylic resin tooth or a regular inlay wax. It is reduced to a thickness of approximately 1.0 mm. to save gold.

A wax reinforcing bar is laid between both abutments and is held a slight distance from the ridge by means of small wax ties. The ties are removed after the bar connecting the two abutment patterns is secured. Finally, the occlusal portion is connected in position, and the one-piece cast wax pattern is completed. Two or three wax sprues are attached and connected at the top.

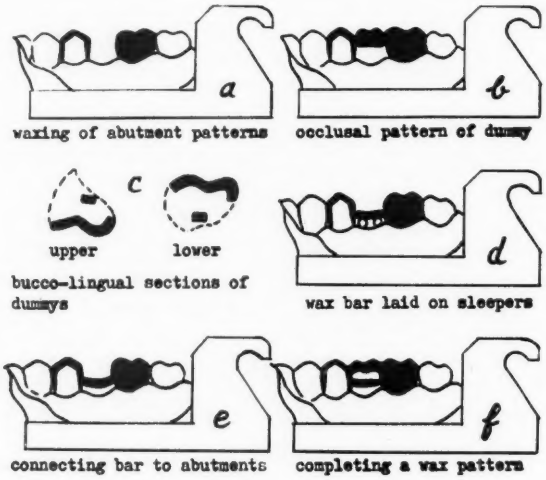

Fig. 8.—The steps in waxing a one-piece cast fixed partial denture.

By using the one-piece cast technique, a fixed partial denture can be made with more accuracy than by using the usual soldering technique. Dimentionally perfect fixed partial dentures are difficult to achieve by the soldering technique, because of the disharmony between the thermal expansions of metal and the soldering investment. The time required to make the one-piece casting is also much less than that for the soldering method. A one-piece cast fixed partial denture has no weak point such as the solder joint.

CASTING RINGS AND LINING

Casting rings of four different sizes were designed (Fig. 9, *a*). The size of rings is indicated in Table II. Rings *A, B, C,* and *D* are used respectively for small inlays, large inlays or crowns, 3 to 4 tooth fixed partial dentures, and 4 to 7 tooth fixed partial dentures. Ring *B* is the most popular size in the United States. The

capacities of the four rings are in the proportion 1:2:4:8, and thus the proportioning of investment and water is accomplished with simplicity and accuracy by using a plastic measuring scoop (Fig. 9, *b*) and a plastic measuring cylinder (Fig. 9, *c*). These plastic measures were made originally for measuring the alginate and water; however, they are adequate for proportioning the refractory investment* and water, since the rings were designed for this purpose. The lowest of the three original

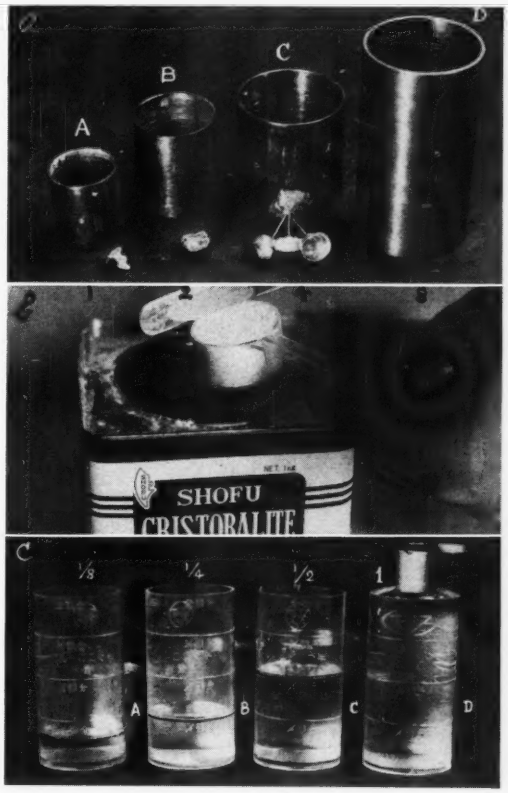

Fig. 9.—*a*, Four standardized casting rings and the measurement of investment and water for them. Rings *A*, *B*, *C*, and *D* are used for inlays, crowns, small fixed partial dentures, and large fixed partial dentures. *b*, One scoop of investment weights 18 Gm. *c*, The whole cylinder is 50 ml.; lines are cut for ¾, ½, ¼, and ⅛.

lines was cut to indicate the amount of water to mix with alginate for a ¼ jaw size impression. It also indicates the amount of water to mix with the investment for ring *B*, with a water/powder ratio of 0.35. A new ⅛ line for ring *A* should be cut half the height of the ¼ line.

The metal rings are lined with a soft dry asbestos ribbon to secure the desirable investment expansion. The asbestos ribbon (Fig. 10) is 0.4 mm. thick and soft enough even in its dry state. The absolute amount of investment expansion

*Shofu cristobalite, 1.6 per cent total expansion (0.3 per cent setting and 1.3 per cent thermal).

varies, depending on the size of the rings, and so different thicknesses of asbestos are needed for the various ring diameters. The desired lining thickness is shown in the lower part of Table II, and the length of the asbestos ribbon necessary to produce the desired lining thickness in respective rings is shown in parentheses. When Ransom & Randolph's experimental investment of 2.0 per cent total expansion is used, one thickness of the asbestos ribbon should be added to each lining.

Fig. 10.—Shofu asbestos ribbon, which is soft in its dry state.

The following procedure is used for lining rings with dry asbestos. The asbestos ribbon is cut in a length specified in Table II. For ring *A*, the width of ribbon is reduced by 5 mm.; for ring *D*, the width is doubled by connecting two original ribbons with a vinyl cement. Then the ribbon is folded into a thickness specified and ready for use (Fig. 11, *a*).

The folded ribbon is bent into heart form and inserted in a ring (Fig. 11, *b*). The meeting of two ribbon ends (Fig. 11, *c*) is pressed against ring wall (Fig. 11, *d*), and thus the retention in the ring is obtained. The ring is tapped on a flat surface to cause the ribbon to go to one end of the ring (Fig. 11, *e*). Then the

TABLE II. SIZE OF FOUR CASTING RINGS, THICKNESS OF LINING, AND PROPORTIONING OF INVESTMENT MIX

SYMBOL	CASTING RINGS		INDICATION (USED FOR)	PROPORTIONING OF SHOFU CRISTOBALITE INVESTMENT AND WATER		LINING WITH SHOFU ASBESTOS RIBBON		
	DIAMETER (MM.)	HEIGHT (MM.)		POWDER	WATER	THICKNESS	LENGTH (CM.)	WIDTH (MM.)
Ring A	24	30	Small inlay	1 scoop (18 Gm.)	⅛ measure (6.25 c.c.)	3 thicknesses = 1.2 mm.	21	25
Ring B	30	38	Crown	2 scoops (36 Gm.)	¼ measure (12.5 c.c.)	4 thicknesses = 1.6 mm.	35	30
Ring C	40	40	Small bridge	4 scoops (72 Gm.)	½ measure (25 c.c.)	5 thicknesses = 2.0 mm.	60	30
Ring D	40	80	Long bridge	8 scoops (144 Gm.)	1 measure (50 c.c.)	5 thicknesses = 2.0 mm.	60	60

ribbon is thoroughly covered by a coating of petroleum jelly or cocoa butter to prevent any water absorption from the investment mix (Fig. 11, *f*). The wax patterns and casting rings are now ready for investing (Fig. 11, *g*).

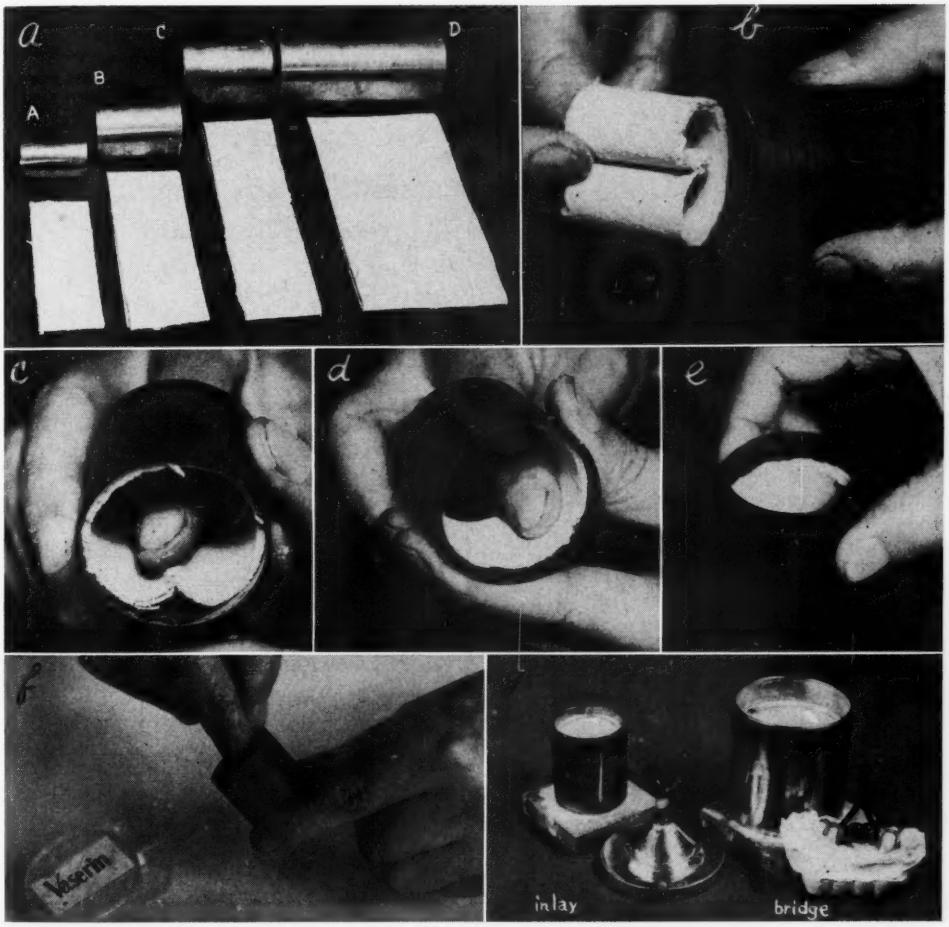

Fig. 11.—Procedure of lining the casting rings with dry asbestos ribbon. *a*, The ribbon is cut and folded in a specified length, width, and thickness. *b*, It is bent in the form of a heart and inserted in a ring. *c*, The meeting of two ribbon ends. *d*, The ends are pressed against ring wall. *e*, The ring is tapped on the bench top. *f*, The dry asbestos lining is coated with petroleum jelly. *g*, The patterns and rings are ready for investing.

The crucible former is made of chromium-plated brass or of rubber. It was designed for use in combination with the afore-mentioned rings for investing wax patterns, except for fixed partial denture patterns (Fig. 12). This crucible former contains a hole with an undercut. The hole is filled with a soft wax into which a sprue wire is inserted at the correct height. The hole is 6 mm. in diameter so that several sprue wires with small inlay patterns can be invested and cast at one time.

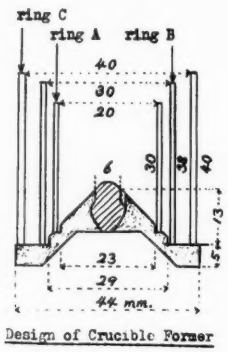

Fig. 12.—A single crucible former is used for different size rings.

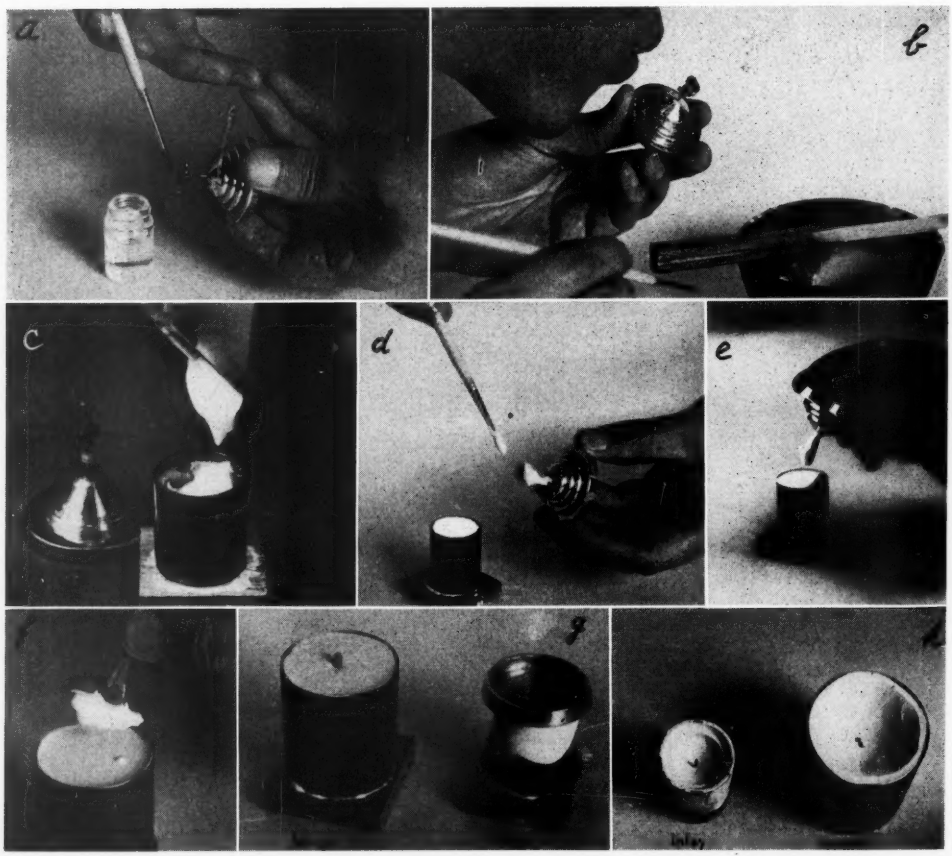

Fig. 13.—Procedure of the insert-investing technique. *a*, The pattern is washed with alcohol. *b*, A thin film of refractory investment mix is painted carefully on the pattern surface. *c*, The investment mix is poured into the ring. *d*, The pattern is covered with a 2.0 to 3.0 mm. thickness of investment mix. *e*, The pattern is forced gently into the investment mix in the ring. *f*, A fixed partial denture pattern with wax sprue is also invested in the same way. *g*, The investing is completed. *h*, The crucibles are made.

Such a combination of specified casting rings, crucible former, investment measures, and lining materials contributes to a simplification of clinical procedures and insures constant, accurate results.

INVESTING PROCEDURE

Some vacuum investing machines produce smooth castings; however, an investing technique which eliminates any bubbles or pinholes, without a vacuum machine, has been developed.

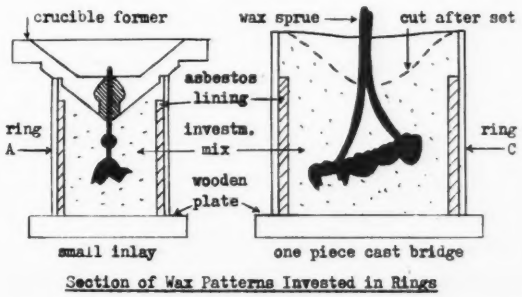

Fig. 14.—A schematic drawing showing the location of wax patterns and asbestos linings in invested rings.

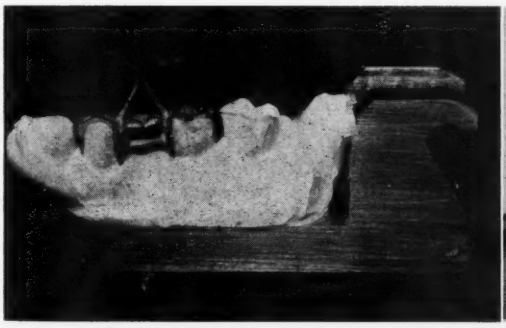

Fig. 15.

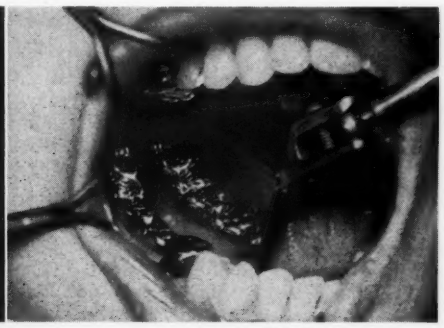

Fig. 16.

Fig. 15.—A fixed partial denture casting placed on an indirect model.
Fig. 16.—A completed fixed partial denture in the mouth.

The wax pattern is washed with a camel's-hair brush dipped in alcohol or soap solution, to remove any oily substance from the pattern surface (Fig. 13, *a*). The refractory investment is mixed in the specified proportion. The surface of the wax pattern is coated carefully with a thin film of investment mix to prevent air bubbles from forming. If the film is not thin enough that the wax color is visible, the elimination of air bubbles cannot be checked. A thick film should be blown off (Fig. 13, *b*).

The refractory mix is poured first into a ring placed on a wooden plate (Fig. 13, *c*). The rest of it is applied to the wax pattern covering it with a 2.0 to 3.0 mm.

thickness (Fig. 13, *d*). The crucible former with the pattern attached is inverted, and the pattern is forced gently into the investment-filled ring with a slight up-and-down movement (Fig. 13, *e*) until the crucible former and the ring are in contact. A one-piece cast fixed partial denture pattern is invested following the same procedure, except that no crucible former is used (Fig. 13, *f*).

After the investment sets (Fig. 13, *g*), the wooden plate is removed, and a crucible is formed by removing the crucible former or by reducing the amount of investment on the ring top (Fig. 13, *h*). The sections of an inlay pattern and a fixed partial denture pattern invested in rings are seen in Fig. 14. The completed molds should be preheated to 700° C. (1300° F.) before casting.

Precision castings of desired dimensional change, minimal distortion, and smooth excellent surface can be produced with no difficulty by this investing technique. No complicated apparatus is needed. Fig. 15 is a three-tooth bridge on the working model. Fig. 16 is a four-tooth bridge set in the mouth.

SUMMARY

A clinical procedure for making precision casting restorations has been described. The procedure follows the conditions specified in previous experimental research. Consistent success has been obtained by this technique, with minimal amounts of time, labor, and materials.

The author wishes to thank Dr. R. Higaki, Dean, Dental School, Tokyo Medical and Dental University, for reviewing this paper, and Major R. H. Crimmel, U. S. Army, for his help on the English translation.

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IMPLANT DENTURES

EQUILIBRIUM WITH SUBPERIOSTEAL COMPLETE DENTURE IMPLANTS*

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NATURAL TOOTH ROOTS may be considered as pillars embedded in bone, which possesses variable degrees of resistance. The resistance of the bone must be able to neutralize the occlusal pressure distributed through the roots if general equilibrium is to be maintained.

The abutment posts serve as the pillars for the support of implant dentures. Therefore, several fundamental factors are involved, and the equilibrium is modified.

SUBSTRUCTURE

Framework of the Substructure.—The pillars are strengthened by a meshwork or framework which connects with the bony support and transmits occlusal pressures to the bone (Fig. 1). The framework must be thin so that it will occupy little space between the bone and mucoperiosteum.

The amount of perforation of the framework is important. The more the framework is perforated, the more its surface support is diminished and the greater is the risk of not neutralizing the occlusal pressure, which then becomes traumatizing. The basic resistance therefore depends on, in addition to the quality of the bone, the degree of support of the substructure to insure the functional prosthetic equilibrium through the abutment posts.

The framework must be in perfect contact with the bone, which is stripped of its resilient covering. The capacity of support depends upon the nature of the bone. The implant-bearing surface must be dense or compact bone and must present a smooth surface in the horizontal plane. Cancellous bony surfaces should be avoided as much as possible. It is necessary to distinguish between the implant-bearing surfaces of the substructure and the sagittal and frontal bracing zones.

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*La biostatique des prothéses complétes avec implants souspériostés. Translated by Paul Friedman.

**Professor, Institute of Dental Medicine, University of Geneva.

The design of the substructure depends upon careful intraoral and roentgenographic examinations. The implant framework guides the surgeon in the type of incision and the necessary amount of retraction of the mucoperiosteal flaps to make the impression of the bone.

Space Necessary for the Substructure.—The substructure (Fig. 2) must be placed between the mucoperiosteum and the bone. When the threshold of tissue distension is passed, the implant is uncovered and failure results. Therefore, sufficient space must be provided surgically to prevent distention of the soft tissue. The removal of the mucoperiosteum from the bone in the implant-bearing surface of the future substructure is obtained by rongeurs, bone drills, and bone files. Notches and grooves are made in the bone to provide the necessary space for the substructure (Fig. 3). Thus, tissue distention when the mucoperiosteal flaps are sutured is prevented.

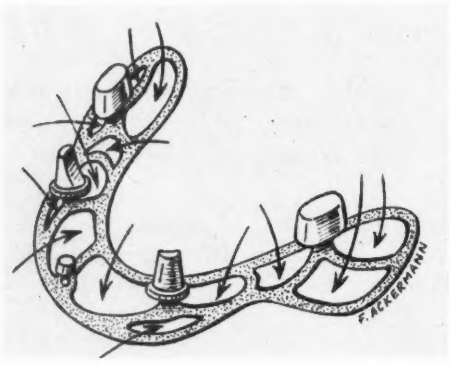

Fig. 1.

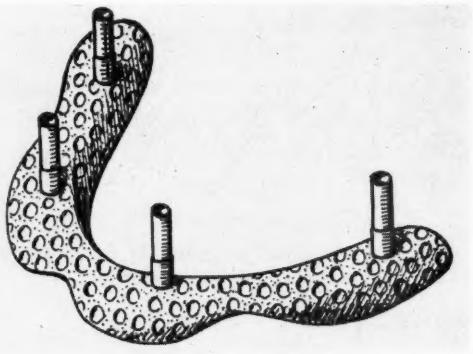

Fig. 2.

Fig. 1.—A subperiosteal implant framework is cast in chrome cobalt. The framework is made up of four main Y-struts, three transverse struts, four abutment posts in the regions of the cuspids and first molars, and an incisive abutment.

Fig. 2.—A usual substructure with four transverse struts.

The extent of the positive surface support of the substructure and the added factors of tolerance, strength, and indeformability dictate the choice of materials—inert metals and alloys. The substructure should be monolithic; therefore, casting is advantageous. The technique provides a substructure with exact adaptation to the bone.

The substructure casting must be examined by endoscopic roentgenograms to insure its perfect homogeneity. Otherwise, the risk of fracture is present.

Fixation of the Substructure.—The fixation may be anatomic or mechanical (grooved notches or screws). Experiments and clinical observations *may* indicate the use of screws.

Screws are temporary elements of fixation and are attached to the thickest portions of cortical bone (the sagittal palatine suture, base of the vomer bone for the maxillae). The notches and grooves, 1.0 to 2.0 mm. deep, in the bone aid in stabilizing the substructure. Screws cannot be utilized in the bicuspid and molar regions of the maxillae.

Extensive contact between the mucoperiosteum and the bone through the substructure is necessary to facilitate the reattachment of the mucoperiosteum to the bone. The reattachment is increased in strength as the substructure is diminished in thickness and increased in interspaces. The mucoperiosteum, not the bone, furnishes the periosteum of reattachment. The bone must be stripped superficially of its resilient fibrous covering and trimmed to present a smooth clean surface.

Composition of the Substructure Pillars.—The substructure pillars are composed of two parts: the intramucosal parts of the implant posts, which are unpolished, sandblasted, rounded elements; and the abutments which are smooth, anchoring elements. A shoulder at the base of the abutment protects the epithelial attachment, or "epithelial cuff." The shape and size of the pillars depend on the pre-established arrangement of the teeth.

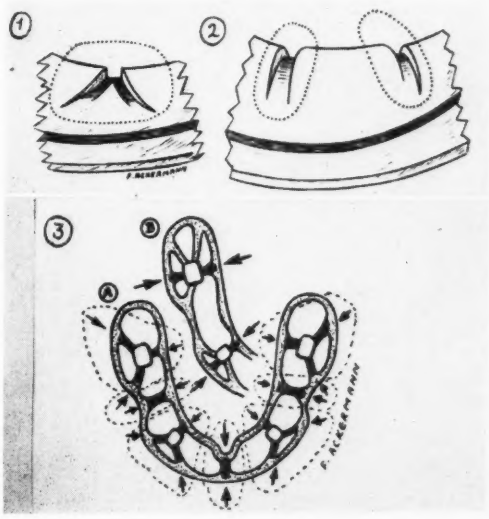

Fig. 3.—Bony notches are created for the substructure. *1*, The reversed-Y type (Ackermann). *2*, The transverse type (Maurel). *3*, The dotted lines indicate seven areas of support of the substructure; *A*, the abutments are connected with Y-struts and transverse struts; *B*, the abutments with the connecting struts create four areas of bony support.

The height of the implant posts is determined by the thickness of the mucoperiosteum and by the expected extent of tissue healing. The pillars are mounted by using a surveyor (parallelometer). The position of the abutment posts is determined by an abutment locator from the pre-established arrangement of the teeth.

PROSTHETIC PREOPERATIVE SETUP

An extremely accurate arrangement of all of the teeth is necessary before the surgical procedures are to be carried out. This setup shows the general plan of the implant denture (architectonic implant).

Fundamental Requirements for the Preoperative Setup.—All of the steps involved in complete denture construction are necessary for the preoperative setup.

The correct vertical dimension, centric relation, and esthetic goals must be established. The posterior teeth are arranged in balanced occlusion with a narrowing of the occlusal surfaces of the cuspids to diminish functional pressures (horizontal pressure). The occlusal forces are directed lingually, with the greatest force in the region of the second bicuspid and first molar teeth. Occlusal corrections are made when the implant is completed. Abrasive paste is contraindicated because of its irritating properties. An adjustable articulator is used.

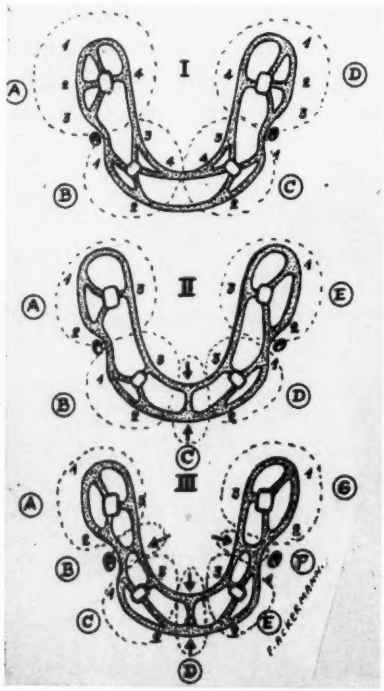

Fig. 4.—*I,* A usual cast framework with four abutments and several struts. *II,* A framework with four abutment posts, Y-struts, and a symphyseal strut *(C). III,* The usual four abutment posts are supplemented by a fifth incisive supporting pillar or abutment on the symphyseal strut *(D).* Y-struts and transverse struts add support. The result is a static type of support with large contact between the bone and the fibromucosa.

EQUILIBRIUM OF THE SUBPERIOSTEAL IMPLANT DENTURE

The completed preoperative setup determines whether the denture implant is satisfactory with regard to its functions and also determines the localization and effects of pressures and antipressures (rocking or traumatizing effects). The abutment posts must support the superstructure and insure its equilibrium and stability during function. Four abutment posts (cuspids and first molars) are insufficient to anchor denture implants. A fifth post should be added in the incisor region (Fig. 4). The loosening of the mucoperiosteum in the region of the incisive foramen does not cause any physiologic inconveniences in nutrition and sensibility.

Placement of the abutment posts is decided by taking into consideration the effects of alveolar resorption, which may uncover the framework buccally and cause

partial or complete failure. The substructure should rest on the hardest and most resistant bony parts (palatine and symphyseal regions, etc.). The alveolar regions are considered slightly resisting or nonresisting zones. It is necessary, therefore, to choose the thicker, more resistant cortical zones (Figs. 5, 6, 7, and 8).

INDIVIDUAL IMPRESSION

The impression is made rapidly and with extreme precision in an individual border-molded, self-curing acrylic resin tray. There must be no interference with muscle attachments. Modeling compound gives excellent results, but the final im-

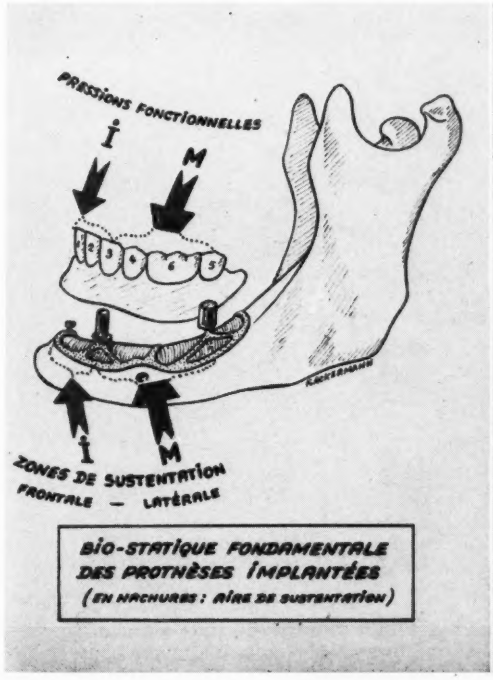

Fig. 5.

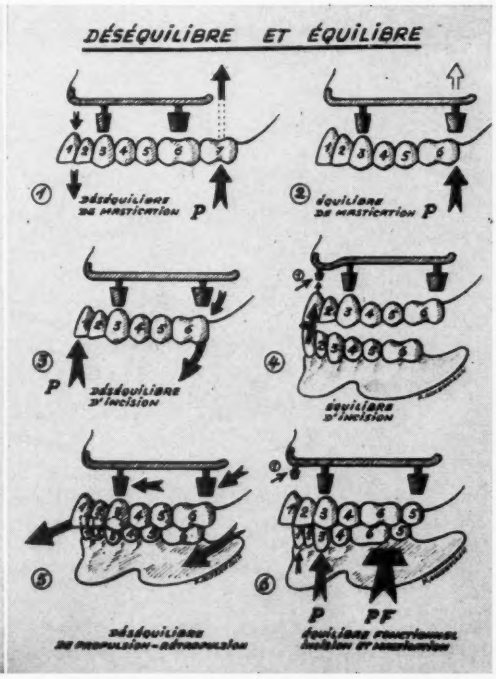

Fig. 6.

Fig. 5.—The fundamental equilibrium of implanted prostheses. The shaded area represents the area of support. *I*, The region of incision. *M*, The region of mastication. The functional pressure must be mesial to the cuspid and first molar abutments. For this reason, the first molar is placed ahead of the second bicuspid. The symphyseal abutment neutralizes the forces of incision.

Fig. 6.—Equilibrium and nonequilibrium. *1*, Pressure on the second molar causes nonequilibrium. *2*, Pressure on the first molar causes equilibrium. *3*, Incisive pressure with no incisive abutment present causes rocking. *4*, The incisive pressure is neutralized by the incisive abutment post. *5*, Incisive interference causes nonequilibrium. *6*, Lack of incisive interference adds to equilibrium.

pression can be made with silicone or alginate (irreversible hydrocolloid) impression materials. The retraction of the mucoperiosteal flaps must be sufficient to permit the making of the impression.

The superstructure is constructed as soon as the substructure is completed. The superstructure is cast of the same metal or alloy as the substructure.

An immediate or temporary splint or implant denture is necessary to orient the regeneration of the connective tissue to bone fibers. Without the immediate splint, fibrous regeneration is anarchic.

COMPLETING THE DENTURE IMPLANT

Because of the precise preoperative setup, the denture implant gives the patient the benefits of high quality occlusion, phonetics, and esthetics, and also combines the qualities of balance and stability. Selective grinding of the teeth prevents the eventual defects of occlusoarticulation and completes the general equilibration. Periodic controls and recommendations are necessary.

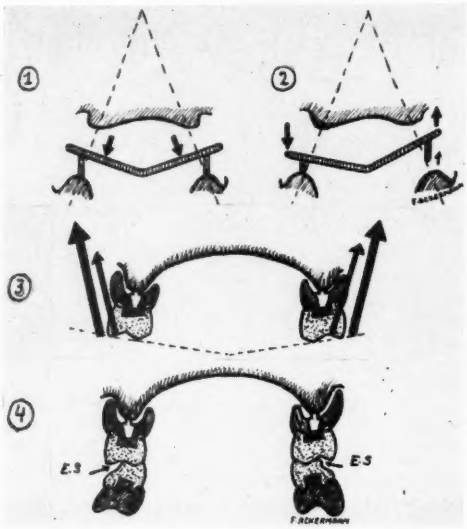

Fig. 7.—Transverse equilibrium. *1*, Forces that fall within the triangle maintain equilibrium. *2*, Forces that fall outside the triangle cause nonequilibrium. *3*, Vestibular forces cause nonequilibrium. *4*, Subocclusal spaces help reduce the transverse rocking.

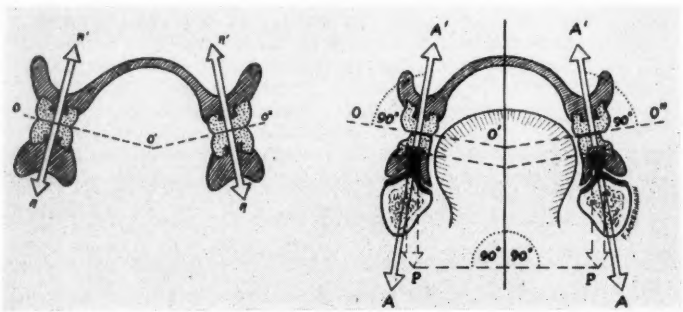

Fig. 8.—*Left*, The resultant forces, *AA'*, are nonfavorable. *Right*, Selective reshaping of the teeth creates favorable forces. The subocclusal spaces reduce vestibular unseating forces. The main pressure of the implant is in a lingual direction.

CONCLUSIONS

The subperiosteal complete denture implant depends fundamentally on the preoperative trial dentures, which must be precisely constructed. These prostheses reveal the architectonic of each denture implant. The stability of the denture implant is differentiated from other dentures in that its substructure rests on bone and not gingivae. This denture implant basically exalts the discipline of odontology (complete and partial dentures) and also the discipline of stomatology because of its equally essential, very delicate accessory role. The subperiosteal technique requires, as an absolute necessity, teamwork among two skilled specialists and an excellent laboratory technician. The satisfaction of a large number of pleased patients demonstrates that subperiosteal complete denture implants are odontostomatologic acquisitions.

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ONE-DAY PROCEDURE FOR COMPLETE LOWER VITALLIUM IMPLANTS

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IMPLANT DENTURES have come to occupy a definite place in dentistry. While every precaution should be taken in the selection of patients and in the execution of the exacting technique, the procedure will be used more frequently in the future.

It is evident that with a rather new technique there is a constant search for improvements. In this article we wish to report on a technique which was developed, whereby a complete lower Vitallium implant can be inserted within 8 to 9 hours in the same day.

The procedure of implantation has passed through different stages of development.[1-8] At present, the method practiced by most dentists is a two-stage procedure. The first stage consists of making the surgical bone impression; the implant is inserted during the second stage, which is usually about 6 weeks after the first operation. While this method has given very good results, it has several serious physiologic as well as psychologic disadvantages.

Physiologic Disadvantages.—The second operation is performed exactly in the same place as the first one. The line of incision for the second operation is identical with the first one. Scar tissue does not have the same reparative powers as other tissues; therefore, reincision should be avoided if possible.[9]

Psychologic Disadvantages.—The fact that the patient has to undergo two separate operations is an obvious disadvantage. This undoubtedly accounts for the hesitation which many patients have in accepting this kind of treatment. Many patients would be willing to undergo this procedure once and have it completed. However, the necessity of submitting twice to the "knife" makes this operation appear as a major surgical intervention and brings with it all the natural fears and hesitations patients normally feel toward surgery.

These reasons make it obvious that the reduction of the interval between the two stages to such a degree that they become, practically, one single operation would be extremely welcome. Many authors are theoretically in favor of such a procedure.[9-11] Gershkoff and Goldberg[12] also look on the performance of two operations as a disadvantage, but do not believe a one-day procedure to be biologically sound. Most of these arguments, however, have been on theoretic grounds, and no practical proofs have been adduced for either view.

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Some authors[10,13,14] have attempted a one-day procedure, but only in exceptional cases and with rather mixed feelings about the results. It is noteworthy that the desire to reduce the time interval between impression and insertion made Marziani[11] look for another material (tantalum) out of which an implant could be fabricated in less time.

Fig. 1.

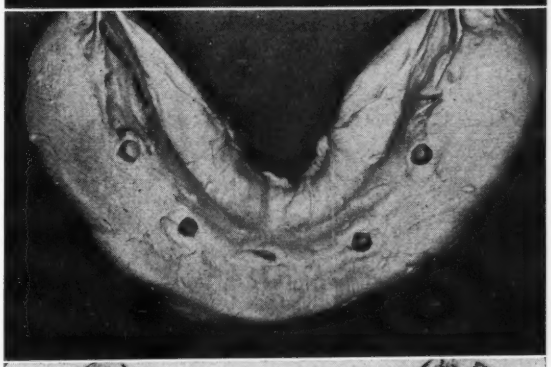

Fig. 2.

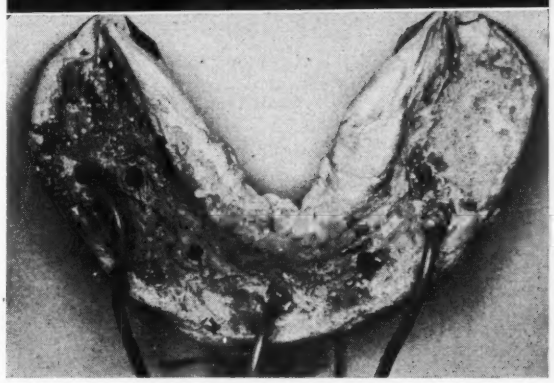

Fig. 3.

Fig. 1.—A copper-plated cast of the implant abutments.
Fig. 2.—A zinc oxide and eugenol impression wash of the abutments made in a modeling compound impression.
Fig. 3.—Copper-plating the impression.

MATERIALS AND METHOD

This report is based on 6 lower Vitallium implants, each having been finished in one day. Five of these were for patients, while the sixth was an experimental one in a rhesus monkey.

The First Surgical Phase.—The surgical bone impressions were made in the early morning. The technique developed by Bodine was used.[5,7] At this stage of the procedure, several biopsies were taken in each instance and, after the bone impression and jaw relation records were completed, the two flaps were held in place by interrupted sutures along the residual ridge.

Fig. 4.

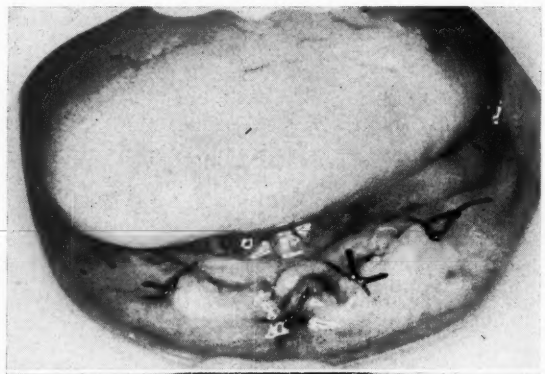

Fig. 5.

Fig. 6.

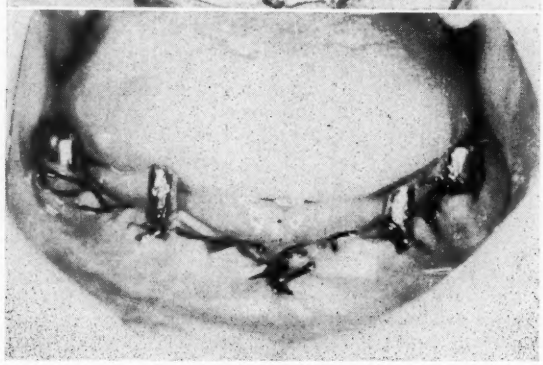

Fig. 4.—The tissues at the beginning of the second (insertion) stage.
Fig. 5.—The bone at the beginning of the second (insertion) stage.
Fig. 6.—The clinical appearance 5 days postoperatively.

When this phase of the procedure was completed, the patient was put to rest and barbiturates and analgesics were administered.

During the ensuing 8 hours the technical operations involved in fabricating the implant were carried out. Two substructure castings were prepared so that an alternate one would be available if the first one was not usable.

The Second Surgical Phase.—The substructure was inserted 8 to 9 hours after the first phase was completed. The premedication and anesthesia used were similar to those of the morning session. Biopsies were obtained again at the beginning of this phase of the operation. The wound was freshened, surplus tissue was removed,

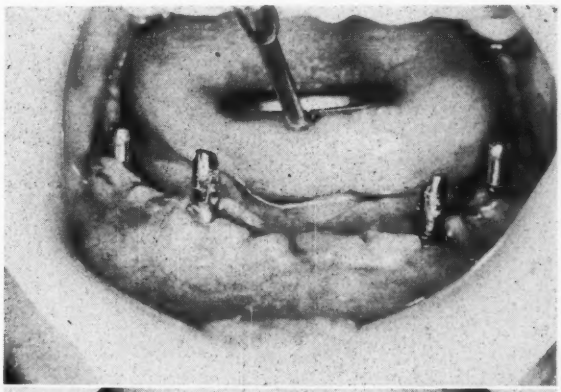

Fig. 7.

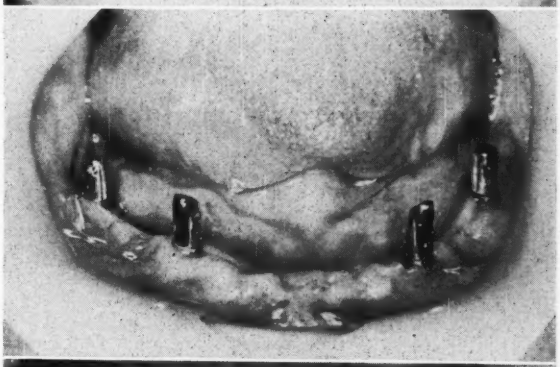

Fig. 8.

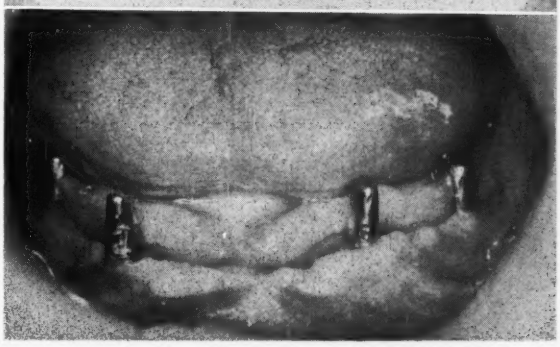

Fig. 9.

Fig. 7.—The sutures were removed 9 days postoperatively.
Fig. 8.—The tissues 16 days after the operation.
Fig. 9.—Clinical appearance of the tissues 4 months after insertion.

and normal bleeding was obtained. After the substructure was inserted and sutured definitely in place, the temporary superstructure was inserted. The temporary superstructure was intended to serve also as a surgical splint.

About 6 weeks after the insertion of the substructure (implant), the permanent superstructure was made. Several difficulties presented themselves in this connection. When the implant is made during an interval of 6 weeks between the impression and the insertion, the superstructure is fabricated and adapted directly on the substructure. Obviously this is impossible in a one-day procedure, and it was difficult to obtain a cast of the abutments which was hard enough to withstand the procedures required for the adaptation of the Vitallium superstructure. Stone casts made from alginate or hydrocolloid impressions were not satisfactory. A copper-plated cast (Fig. 1) was found to overcome this difficulty. A modeling compound impression was made first, and then a zinc oxide and eugenol paste wash impression was made in it (Fig. 2). This impression was electroformed in copper (Fig. 3), and the resultant cast proved to be satisfactory and withstood the adaptation procedures for the superstructure without loss of accuracy.

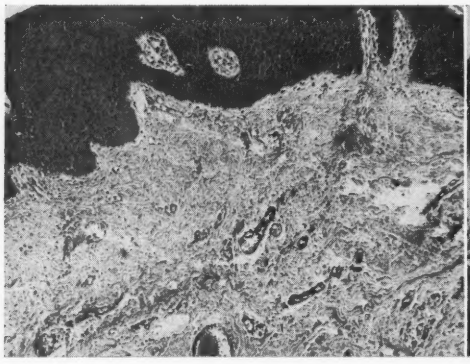

Fig. 10.

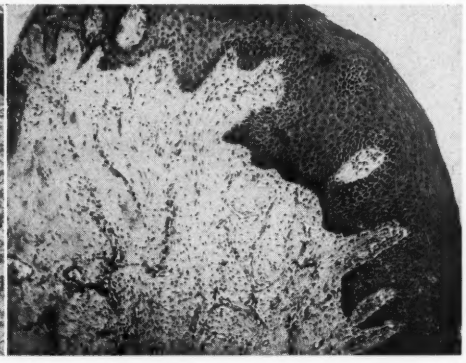

Fig. 11.

Fig. 10.—Photomicrograph of biopsy taken at the *first* (impression) stage of the operation. (Hematoxylin-eosin, ×90; reduction 4/9.)

Fig. 11.—Photomicrograph of biopsy taken at the *second* (insertion) stage of the operation. (Hematoxylin-eosin, ×90; reduction 4/9.)

RESULTS AND DISCUSSION

While the advantages of this procedure are obvious, further investigation was necessary before it could be recommended as routine.

Reaction of the Patients.—All the patients were unanimous in their enthusiastic support of this procedure, since they finished their "ordeal" in one single day and had temporary dentures at the end of the day.

If the patients were given proper premedication at the beginning of the first stage of the procedure and later on during the day were judiciously medicated with barbiturates and analgesic drugs, they usually slumbered drowsily during the entire waiting period. They did not complain of undue pain or discomfort. Ice packs were used to minimize the amount of edema.

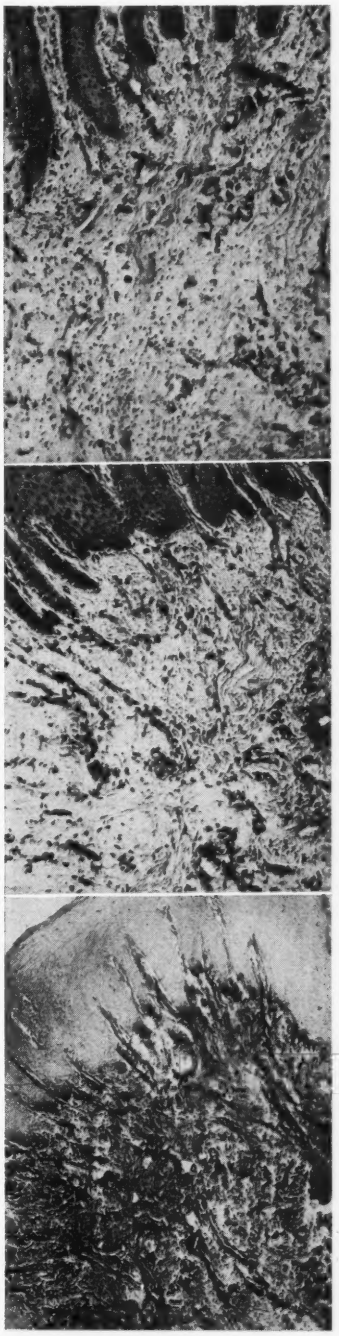

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 12.—Photomicrograph of biopsy taken at the *first* stage of the operation. (Hematoxylin-eosin, ×90; reduction 4/9.)

Fig. 13.—Photomicrograph of biopsy taken at the *first* stage of the operation. (Hematoxylin-eosin, ×160; reduction 4/9.)

Fig. 14.—Photomicrograph of biopsy taken at the *first* stage of the operation. (Trichrome stain, ×90; reduction 4/9.)

Fig. 15.

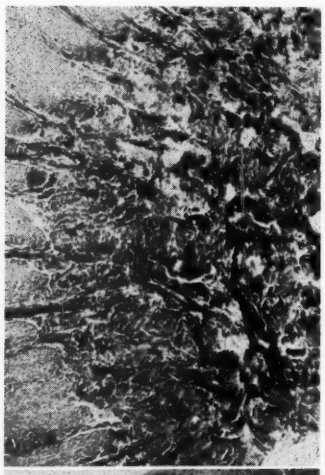

Fig. 16.

Fig. 17.

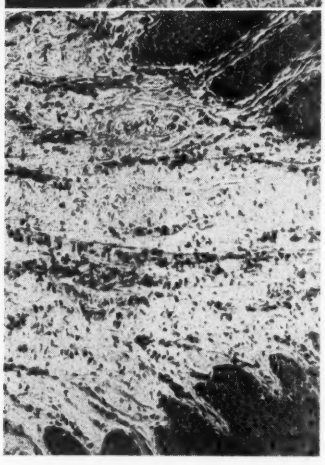

Fig. 15.—Photomicrograph of biopsy taken at the *first* stage of the operation. (Trichrome stain, ×160; reduction 4/9.)

Fig. 16.—Photomicrograph of biopsy taken at the *second* stage of the operation. (Hematoxylin-eosin, ×90; reduction 4/9.)

Fig. 17.—Photomicrograph of biopsy taken at the *second* stage of the operation. (Hematoxylin-eosin, ×160; reduction 4/9.)

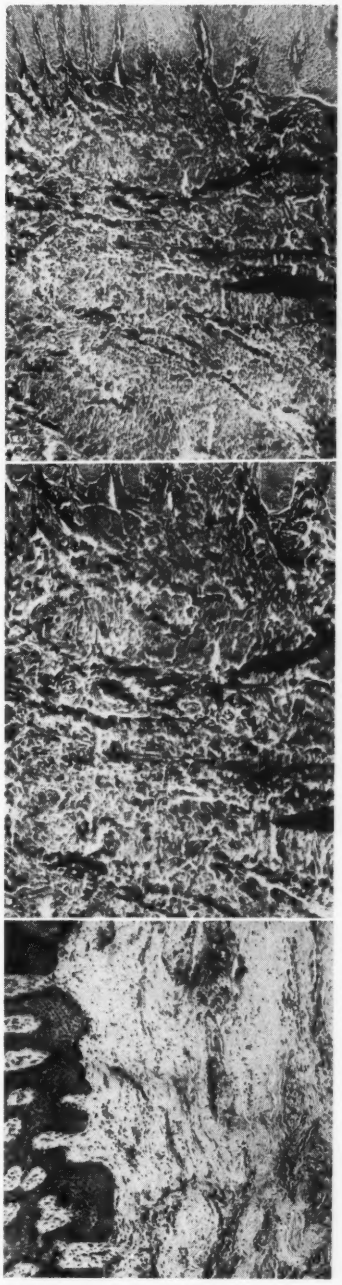

Fig. 18.

Fig. 19.

Fig. 20.

Fig. 18.—Photomicrograph of biopsy taken at the *second* stage of the operation. (Trichrome stain, ×90; reduction 4/9.)

Fig. 19.—Photomicrograph of biopsy taken at the *second* stage of the operation. (Trichrome stain, ×160; reduction 4/9.)

Fig. 20.—Photomicrograph of biopsy taken at the beginning of the *second* stage of the operation. (Hematoxylin-eosin, ×90; reduction 4/9.)

Reaction of the Tissues.—The cardinal question was in what state the tissues would be found at the end of the 8 to 9 hour waiting period. Had local tissue shock occurred; was there undue interstitial edema; was there an infiltration of inflammatory cells; and had the tissues retained their full reparative powers? Other questions were to what extent the reparative formation of the granulation tissue had progressed and whether this delicate process of healing would be interrupted by the new trauma.

Macroscopic Observations.—Tissue trauma, as mentioned by Gershkoff and Goldberg,[12] was not noted in any instance. At the beginning of the second phase the tissue looked pink and healthy (Fig. 4), and bled normally. The color of the blood was normal, and that of the bone surface was normal, too (Fig. 5). The tissues did not lose their elasticity, and no friability was noted during suturing. Healing was normal and uneventful in all subjects, except around several abutments where it took place by secondary intention (Figs. 6 to 9).

Microscopic Findings.—The biopsies, which were taken in all 6 cases, were embedded in paraffin and sections of 6 μ thickness were obtained. These were stained with hematoxylin-eosin, a modification of Mallory's connective tissue stain and a modification of Masson's trichrome stain.

The microscopic pictures of the biopsies taken at the beginning of the second phase were similar to those taken after the same interval following normal oral surgical procedures. Some edema was present, but it was not excessive. This edema has to be considered normal for a postoperative biopsy. There was no undue infiltration of the tissues by inflammatory cells, except where infiltration existed before the first surgical phase and which appeared in the biopsy taken during the first phase. There was almost no evidence of the beginning of formation of granulation tissue.

A comparison of biopsies taken during the first and second phases shows essentially the same picture, except for the slight edema and widening of the blood vessels which was due to the operative procedures (Figs. 10 to 20).

The macroscopic and the microscopic examinations indicate that the tissues did not suffer from the 8 to 9 hour interval during which they were held by temporary sutures. At the beginning of the second phase the tissues retained their normal reparative powers.

CONCLUSION

The one-day procedure for complete lower Vitallium substructure implants is practical. It simplifies the entire procedure of implantation, and has physiologic as well as psychologic advantages. It can be recommended wherever the necessary laboratory cooperation is available. It is believed that this method will be a factor in making the insertion of dental implants more popular and will contribute to the ultimate well-being of many denture patients.

The authors wish to thank Drs. Landsberg, Rotter, and Lapidoth for their surgical assistance on the respective patients, and Mrs. C. Salomon and Mrs. C. Weinman for their excellent photography.

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The Hebrew University-Hadassah Medical School
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Jerusalem, Israel

SURGICAL PROSTHESIS

AN APPLIANCE WHICH HOLDS RADIOACTIVE NEEDLES FOR TREATING ORAL MALIGNANCIES

HENRY K. YAGGI, D.D.S.
Columbus, Ohio

RADIOLOGISTS USUALLY ENCOUNTER difficulties in placing radioactive needles in the jaws of patients being treated for oral malignancies. A simple prosthetic appliance can be made to overcome these difficulties.

TECHNIQUE OF CONSTRUCTION

Make an alginate impression of the affected area and pour a cast (Fig. 1). An alginate impression material causes the minimum discomfort to the patient, produces the least tissue displacement, and is easily removed from existing undercut and dentulous areas. The radiologist outlines the involved area on the cast and indicates the exact positions of the needles.

Apply a layer of liquid latex directly to the cast with a small camel's-hair brush. No separating medium is needed. Tease the latex around each tooth and into the interproximal areas. This detail of adaptation provides retention for the appliance. Allow the first layer of latex to dry, and repeat the procedure until the latex has been built up to within 1.5 mm. of the desired bulk.

Place the needles in their designated positions, and add sufficient latex to cover them and hold them in position (Fig. 2).

When the latex is completely cured, a roentgenogram of the appliance on the cast is made to be sure that the needles were retained in their correct positions (Fig. 3).

Necessary changes or corrections are made before removing the appliance from the cast. After the bulk and the positions of the needles have been checked, remove the appliance from the cast and trim it to its predetermined outline (Fig. 4).

At the time the appliance is inserted in the mouth, instruct the patient about its care and about its insertion and removal.

Presented as a table clinic before the American Denture Society, Chicago, Ill., Feb. 7, 1959.
Received for publication Jan. 5, 1959.

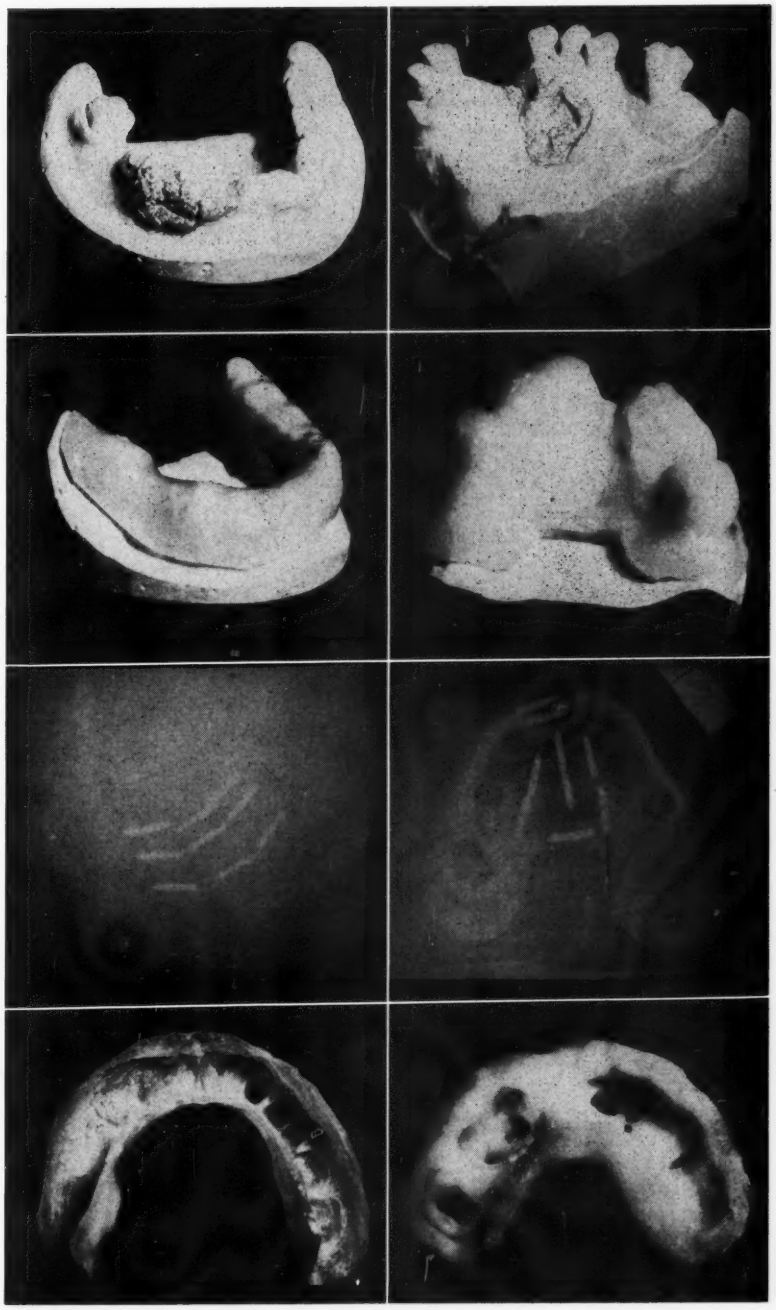

Fig. 1.—Casts showing the affected areas.

Fig. 2.—The latex appliances on the casts. The radioactive needles are contained within the latex appliance.

Fig. 3.—Roentgenograms showing the location of the radioactive needles.

Fig. 4.—The tissue side of the completed appliances. Note the retention provided by undercuts.

ADVANTAGES

1. This simple appliance makes possible the use of radioactive needles in areas where surgical implantation is either impossible or very unsatisfactory.
2. It permits a prolonged exposure to needles of low intensity, if desired.
3. It provides an accurate means for controlling the amount of radiation.

9 Buttles Ave.
Columbus 8, Ohio

READERS' ROUND TABLE

MINNEAPOLIS, MINN.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

The recent article concerning biting force, "Can Biting Force Be Used as a Criterion for Registering Vertical Dimension?" by L. J. Boucher, T. J. Zwemer, and F. Pflughoeft, is as interesting as it is stimulating [J. PROS. DEN. 9:594-599, 1959].

In that I have developed and worked with the Boos Bimeter for 23 years, I feel quite familiar with the instrument, the findings, and the various circumstances which may affect the results obtained.

Reference is made to the muscles as the primary background of registration. In the original work, this was considered of great importance. However, the registration simulates the practical application of complete denture bases in function. The physiology of muscle function is very interesting, and there is a great variation of research reported.

Muscles accommodate to environment and state of mind. To be practical, they are used every day with the use of the dentition, and we often hear of individuals who are able to bite more efficiently under different conditions. The condition of muscles, general health, and mental outlook are very important factors affecting the registrations.

Physiologic rest position is a musculature position and is affected by these same factors. Electromyography may record a great variation, so it is difficult to compare registrations unless all of the factors involved have been carefully considered. Unfortunately, the instruments are not automatic when dealing with the human being.

To answer the findings:

1. The original registration was made on 400 patients and a variation of 9 to 132 pounds recorded. The average was 60 to 65 pounds for men, 25 to 30 pounds for women.
2. Acrylic resin baseplates should be very satisfactory.
3. The comparison of techniques indicates a variation which may have been affected by outside factors.

My research indicated correlated measurements. Physiologic rest position was obtained after conditioning and by unstrained plaster records. This is a very positive transfer.

The second factor included in the original research which was not mentioned in the paper was functional areas and their relation to the recording of centric relation by various techniques.

Sincerely,
RALPH H. BOOS, D.D.S.

MILWAUKEE, WIS.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

Dr. Boos states that registration by the Bimeter includes two factors. The first is vertical dimension and the second the functional area. He says the importance of the functional area must be considered. In this I agree wholeheartedly. It may be entirely possible that biting force may be employed in determining the functional area after vertical dimension has been established by some other method. Our experiments, however, were concerned with the feasibility of

using the Bimeter for establishing vertical dimension. The point of issue, as we see it, concerns the third point in Dr. Boos' summary [Intermaxillary Relation Established by Biting Power, J.A.D.A. 27:1198, 1940] where he states, "A constant vertical dimension of maximum power can be determined in the intermaxillary relation by registering the power in various intermaxillary relations."

Sincerely,
Louis J. Boucher, D.D.S.

New York, N. Y.

Editor, The Journal of Prosthetic Dentistry:

This is to comment on your editorial appearing in the September-October issue of the Journal, dealing with Certification of Dental Laboratory Technicians [J. Pros. Den. 9:889, 1959].

From a technician's point of view, this editorial has not only been the first enlightened editorial on the subject appearing in a professional journal, but it has been written with knowledge and a great deal of understanding. It makes the point concisely, but eloquently.

I gather that you have been prompted to write this expression by the report of the Dentist and Dental Laboratory Technician Relations Committee of the Academy of Denture Prosthetics [Dentist and Dental Laboratory Technician Relations 9:886-888, 1959].

May I say that the action of the Academy is a courageous and enlightened one? In my humble opinion, it is a historic one. We in the industry would like to think that the Academy has given expression to sentiments generally prevailing throughout the profession today. It is not accidental, I believe, that the Academy of Denture Prosthetics, through the guidance of men like Dr. A. W. Sears, Dr. C. H. Schuyler, and Dr. R. H. Boos, was the first to do so. This is gratifying and, for one, I am certain that this is but the beginning of the solution of a problem that has been neglected for so long and now has come home to roost.

The Council on Dental Education of the American Dental Association, in cooperation with the National Board for Certification, and the National Association of Dental Laboratories have developed and are fostering the program of Certification for Dental Technicians. This program now needs the sympathetic understanding and active support of all men of good will both in the profession and in the industry.

I construe your editorial to be of such moral support and hope that you will continue to lend your influential voice to the "cause" whenever the occasion arises.

Respectfully yours,
George Klein, C.D.T.
Chairman, Educational Committee
National Board for Certification

BOOK REVIEWS

PRACTICAL EXERCISES IN DENTAL MECHANICS. By F. G. Shaw, L.I.B.S.T., and D. C. Scott. Ed. 2, St. Louis, 1955, The C. V. Mosby Co., Pp. 205, illustrated, indexed. Price $10.00.

The authors have stated that the purposes of this book are: first, to provide a syllabus of beginning exercises for dental students; second, to serve as a guide for certain exercises not familiar to the lone laboratory technician; and third, to provide a volume for reference especially for uncommon techniques. Needless to say, these three aims would be difficult enough to fulfill in three separate volumes.

It is the opinion of the reviewer that this book would be more suitable for the uninitiated dental student. Even for the beginner, some areas of the text outline rather nonspecific instructions (enough, normal thickness, too much, adequate, medium mix, room temperature, etc.). Also, the "Do's" and "Don'ts" included with each exercise might confuse the reader with respect to the proper chronology of the procedure.

This book is divided into three parts. Part One gives a good elementary introduction to the biologic and physiologic structures commonly encountered in the practice of dentistry and includes tooth designation, tooth morphology and carving, the Kennedy classification for partial dentures, and a short glossary of terms.

Part Two, beginning with practical exercises in each area, covers complete denture fabrication, partial denture design and casting, orthodontics, and then briefly, the making of gold inlays, jacket crowns, fixed crown and bridge prosthesis, simple obturators, and splints. Exercises include swaging of special trays and saddle plates, fabrication of an immediate denture without a labial flange, vulcanized and heat-curing denture repairs, and making a gold shell crown. It would seem that an exercise making a self-curing acrylic resin tray (not included in the text) would be of more practical value.

Part Three is devoted to information relating to commonly used dental materials. Their composition, properties, working characteristics, and recommended treatment are discussed and illustrated with several tables which compare the properties of various metals and alloys. The book concludes with a short bibliography and a comprehensive index.

In general, the discussions and exercises are simply and clearly presented with good illustrations, especially the part on surveying and designing partial dentures. This book would probably serve best as an adjunct to those teaching dentistry at the preclinical level.

Julian B. Woelfel, D.D.S.

COLOR ATLAS OF ORAL PATHOLOGY. Prepared under the auspices of the U. S. Naval Dental School of the National Naval Medical Center, Bethesda, Maryland. Philadelphia, 1956, The J. B. Lippincott Company, Pp. 188, illustrated, indexed. Price $12.00.

The general format of an atlas ordinarily incorporates graphic or photographic examples with a substantial but not unduly extensive descriptive written text. This book is concerned with oral diseases per se and oral manifestations of systemic disturbances.

The text is well written. It is presented with clarity and, though concise in volume, it is rich in essential knowledge. The material is presented in sequence under the headings of histology and embryology, developmental disturbances, diseases of the teeth and supporting structures, diseases of the oral mucosa and jaws, and neoplasms.

Illustrations are superb, consisting chiefly of colored photographs of clinical, roentgenographic, and microscopic material. The art work of these reproductions reflects exceedingly fine craftsmanship. The print offers unstrained reading, and topics are introduced with boldface type. A format of two columns per page also enables ease of reading. The book is cloth bound.

This book fills the need for additional atlas material in the field of oral pathology. It has universal appeal to both student and practitioner. The reviewer highly endorses this book.

Steve Kolas, D.D.S.

DYNAMICS OF ORAL DIAGNOSIS. By E. Cheraskin, A.B., M.A., M.D., D.M.D., and L. L. Langley, A.B., M.A., Ph.D., LL.B. Chicago, 1956, The Year Book Publishers, Inc. Pp. 533, illustrated, indexed. Price $16.00.

The chief purpose of a work on diagnosis is to wed methods of procedure to the available facts of a problem and derive a correct conclusion. The text is concerned with the diagnosis of oral disease per se and associated oral manifestations of systemic diseases and relatively brief statements of treatment.

The book is well written, quite lucid, concise where it can be, and detailed where it needs to be to offer continuity. It is compiled into two sections: Part I, Oral Medicine, and Part II, Oral Diagnosis.

Part I is documented in an orderly manner, depicting details of specific diseases. The discussions, generally, include: a definition of the term, pathologic physiology, clinical features, roentgenographic findings, laboratory studies, and treatment.

Part II deals with the methods of acquiring available facts. It discusses the gross appraisal of the patient, examination of the head and neck, and examination of the oral cavity.

As each part or area of the body is presented, its anatomy and physiology are wisely considered as is the significance of pathology. The illustrations used are chiefly black and white clinical and roentgenographic photographs. A liberal supply of good quality reproductions is evident throughout the text.

The character of the print, the use of bold face type at each topic heading, and the double column format all facilitate ease of reading.

It is the reviewer's opinion that the authors have accomplished their objectives, and the book is enthusiastically recommended to all concerned with dentistry.

Steve Kolas, D.D.S.

DENTISTRY FOR CHILDREN. By John C. Brauer, William W. Demeritt, Roy L. Lindahl, L. B. Higley, Maury Massler, and Isaac Schour, ed. 4, New York, Toronto, London, 1958, The Blakiston Division, McGraw-Hill Book Company, Inc. Pp. 492, illustrated, indexed. Price $11.00.

This textbook is written in such a manner that it may be used in various levels of dental teaching, from undergraduate students to the graduate class. It may also adequately serve as a reference book for the general practitioner of dentistry, as well as for various members of the allied professions seeking information pertaining to dental problems.

The material is organized and presented in 18 chapters covering the various areas of pedodontic practice. The six contributing authors have written in a simple and interesting manner that engages the reader's interest. The book is illustrated with well-chosen photographs, charts, and tables, and the printing and binding are of excellent quality.

A philosophy of the practice of dentistry for children, the psychologic development of the child, the nature, treatment, and prevention of dental disease and dental anomalies, as well as the technical procedures involved, all serve to make this an enlightening presentation.

In this fourth edition there have been minor changes in content which have brought the material commendably up to date.

L. S. Pettit, D.D.S.

OPEN DOOR TO HEALTH. By Frederick D. Miller, D.D.S., as told to Edna Yost, A.B., Litt. D., New York, 1959, Devin-Adair Company. Pp. 179, indexed. Price $3.95.

Did you know that there is a dentist in Altoona, Pennsylvania, whose patients include hundreds of young people with caries-free teeth, i.e., they have beautiful, well-developed jaws and no fillings or cavities? This unique dentist is Dr. Frederick D. Miller. In 1912, while at the University of Pennsylvania Dental School, he was deeply impressed by a statement made by Dr. Kirck, the dean. Dr. Kirck, the father of five children, said, "Our children had fine teeth while living at home where we had control of their food habits, but soon after leaving home they all developed bad teeth." This thought planted a seed in Dr. Miller's mind which has been nourished over the subsequent years by observation and intensive study and has finally blossomed in the form of a remarkable book.

The dentist is in a unique position as far as patient education is concerned. In the first place he sees most of his patients regularly; second he has a splendid opportunity to detect early signs of degeneration; and third he has a "captive audience." This book will assist the dentist in his presentation and should be recommended reading for all patients interested in better health and, subsequently, better teeth and supporting tissues.

W. Ward Tracy, D.D.S.

MODIFIKATION DES ARTICULATORS UND DER AUFSTELLREGELN FÜR VOLLPROTHESEN (MODIFICATION OF THE ARTICULATOR AND OF THE RULES FOR SET-UPS FOR FULL DENTURES). By Alfred Gysi, Prof. Dr. med. h.c., Bern, 1958, Hans Huber Publishing Company, and Bern, Stuttgart, and New York, 1958, Intercontinental Medical Book Corporation, Pp. 96, 64 illustrations. Price $3.75.

This book, written by the late "grand old man of balanced occlusion," carries the subtitle, "The effects of the bent, two surface incisal guide table as well as of non-symmetrical condylar paths upon the shape of occlusal surfaces of artificial teeth for full dentures and the resulting rules for the set-up of the teeth."

This long subtitle is very descriptive of the content of the book. The author gives a review of the development of the incisal guide table and proceeds to describe his method for construction of occlusal surface facets by the use of the so-called "shark's teeth," a double row of sharp metal pieces mounted in a block of plaster. These "shark's teeth" are used to establish, by grinding against an opposing plaster block in an articulator, the exact angulations and inclinations of occlusal facets. By change of condylar inclination and by introduction of a V-shaped incisal table, various patterns result, and the author then proceeds to evaluate the various occlusal schemes in terms of static and dynamic considerations.

In a series of tables, the author lists angular values for many occlusal components as a function of variations of sagittal condylar inclination and of sagittal inclination and horizontal angulation of the V-shaped incisal guide table.

The treatment of the subject follows Gysi's previously published analyses of occlusal patterns, and acquaintance with the author's extensive work in this field is a distinct advantage, if not a prerequisite, for the full understanding of his approach.

The quality of the binding, the printing, and the paper is excellent. The illustrations and tables are very clear, but so filled with numerical data that full interpretation thereof is a major task. It is emphasized that the author does not expect the practicing dentist to concern himself with the details of the research procedures described, and several chapters have special paragraphs emphasizing the practical conclusions to be drawn from the theoretical considerations and from the various measurements presented in tables and schematic and geometrical drawings.

The book is important in that it gives an up-to-date account of the development of Gysi's concept of balanced occlusion and illustrates the final refinements in his research methods as well as the practical conclusions of his later studies. Graduate students in prosthodontics, as well as other dentists with genuine interest in problems of balanced occlusion, will find it worth their while to study this book in detail.

Gunnar Ryge, D.D.S., M.S.

NEWS AND NOTES

MEETINGS

Society of Oral Physiology and Occlusion, Hotel New Yorker, New York, N. Y., Dec. 5, 1959. For further information write to Dr. S. M. Kelner, Secretary, 57 West 57th St., New York 19, N. Y.

Greater New York Academy of Prosthodontics, Barbizon Plaza Hotel, New York, N. Y., Dec. 5 and 6, 1959.

Greater New York Dental Meeting, Hotel Statler Hilton, New York, N. Y., Dec. 7 to 11, 1959.

American Equilibration Society, Sheraton-Blackstone Hotel, Chicago, Ill., Feb. 4, 1960.

American Denture Society, Congress Hotel, Chicago, Ill., Feb. 5 and 6, 1960.

American Academy of Restorative Dentistry, Conrad Hilton Hotel, Chicago, Ill., Feb. 6 and 7, 1960.

American Academy of Crown and Bridge Prosthodontics, Conrad Hilton Hotel, Chicago, Ill., Feb. 6 and 7, 1960.

Southeastern Academy of Prosthodontics, Monteleone Hotel, New Orleans, La., April 29 to May 1, 1960.

American Association for Cleft Palate Rehabilitation, Brown Palace Hotel, Denver, Colo., May 12 to 14, 1960. For further information write to Dr. D. C. Spriestersbach, Department of Otolaryngology, University Hospitals, Iowa City, Iowa.

Academy of Denture Prosthetics, La Concha Hotel, San Juan, Puerto Rico, June 19 to 24, 1960.

American Dental Society of Europe, Edinburgh, Scotland, July 5 to 8, 1960.

ANNOUNCEMENTS

Reprints of the "Glossary of Prosthodontic Terms" may be obtained by writing to Glossary Reprints, 3939 Old Brownsboro Road, Louisville 7, Ky. The price is fifty cents per copy, with a 20 per cent discount allowed on purchases of 20 or more copies. Cash, check, or purchase order *must* accompany the order.

Reprints of "Principles, Concepts, and Practices in Prosthodontics" may be obtained by writing to Dr. W. Les Warburton, Secretary-Treasurer, Academy of Denture Prosthetics, 807 Medical Arts Bldg., Salt Lake City 11, Utah. The price is twenty-five cents per copy, with a 20 per cent discount allowed on purchases of 20 or more copies. Cash, check, or purchase order *must* accompany the order.

The American Equilibration Society has issued a leaflet entitled "Treatment for Returning the Lower Jaw to a Condition of Equilibrium." This leaflet explains to the patient, in simple terms, how stress in the temporomandibular joint can cause such troubles as headache, facial pains, dizziness, deafness, nervousness, and others, and how the stress can be removed by means of changing the occlusion of the teeth.

Any dentist or physician may obtain a copy of the leaflet by writing to the Secretary of the Society, Dr. Raymond C. Van Dam, 11431 South Halsted St., Chicago 28, Ill.

The University of Alabama, School of Dentistry, will present a 3 day refresher course in "Preventive Orthodontics" from Dec. 12 to 14, 1959. An outline of this course can be obtained by writing to the Director, Refresher Course Program, University of Alabama, School of Dentistry, 1919 Seventh Ave., South, Birmingham 3, Ala.

The Medical College of Virginia, School of Dentistry, announces the following postgraduate courses:

Clinical Occlusion, Feb. 12 to 16, 1960.

Anatomy of the Head and Neck, March 14 to 18, 1960.

For further information and application, write to Dr. H. T. Knighton, Director of Postgraduate Instruction, Medical College of Virginia, School of Dentistry, Richmond, Va.

The Ohio State University, College of Dentistry, announces the following postgraduate courses:

Bringing Operative Dentistry Up to Date, Nov. 30 to Dec. 4, 1959.

Crown and Bridgework, Jan. 25 to 29, 1960.

Pedodontics, Feb. 15 to 19, 1960.

Endodontics, March 1 to 4, 1960.

General Anesthesia, April 4 to 8, 1960.

Oral Surgery, April 11 to 15, 1960.

Clinical Periodontics, April 11 to 15, 1960.

Partial Denture Prosthodontics, May 2 to 6, 1960.

Complete Denture Prosthodontics, May 9 to 13, 1960.

Dental Drugs in Action, May 19 and 20, 1960.

For further information and application, write to Postgraduate Division, College of Dentistry, The Ohio State University, 305 West 12th Ave., Columbus 10, Ohio.

The University of Pennsylvania, School of Dentistry, announces the following postgraduate courses:

Hypnosis Applied to Dentistry, Nov. 30 to Dec. 2, 1959.

Dentistry for Handicapped Children, Nov. 30 to Dec. 2, 1959.

The Use of Ultrasonics in Periodontics, Dec. 12, 1959.

For further information and application, write to Director, Postgraduate Courses, School of Dentistry, University of Pennsylvania, 4001 Spruce St., Philadelphia 4, Pa.

Temple University School of Dentistry announces the following postgraduate courses:

Clinical Oral Pathology, Jan. 14 to 16, 1960.

Advanced Orthodontics, Jan. 17 to 30, 1960.

Anatomy—Head and Neck Dissection, Wednesdays, Feb. 3 to June 8, 1960.

Periodontal Prosthesis, Feb. 8 to 12, 1960.

Advanced Fixed Prosthesis, Feb. 8 to 13, 1960.

Present-Day Periodontal Practice, 1 day a week for 10 weeks, Feb. 16 through April 26, 1960.

Practice Administration, Feb. 27, 1960.

Clinical Diagnosis and Oral Medicine, Feb. 29 to March 4, 1960.

Electronic Electrosurgery, March 18 and 19, 1960.

Full Denture Prosthesis, March 21 to 26, 1960.

Advanced Surgical Techniques in Periodontal Therapy, April 4 to 9, 1960.

Graduate Orthodontics, a 2 year course, Sept. 12, 1960.

For further information and application, write to Dr. Louis Herman, Director of Postgraduate Studies, Temple University School of Dentistry, 3223 North Broad St., Philadelphia 40, Pa.

The Faculty of Dentistry, University of Toronto, Toronto, Canada, announces a 2 day postgraduate course in Paedodontics to be given at the Faculty of Dentistry on Jan. 11 and 12, 1960.

For further information write to the Chairman, Division of Postgraduate Studies, Faculty of Dentistry, University of Toronto, Toronto, Canada.

Tufts University School of Dental Medicine announces the following postgraduate courses:

Hospital Management for the Dental Patient, Jan. 6 to 8, 1960.

Trouble Shooting in Complete Dentures, to be given on the following Wednesdays: Jan. 6, 13, and 20, 1960.

Crown and Bridge Prosthesis, Jan. 18 to 22, 1960.

Cephalographics and Diagnosis, Jan. 20 to 22, 1960.

Oral Pathology for the Oral Surgeon, each Thursday afternoon, Feb. 4 to March 31, 1960.

Orthodontic Principles of Interest to the General Practitioner, each Wednesday, Feb. 10 to March 30, 1960.

Oral Rehabilitation, Feb. 25 to 27, 1960.

A Demonstration Course in Complete Upper and Lower Dentures, Feb. 11 to 13, 1960.

Minor Oral Surgery, each Wednesday, March 2 to April 6, 1960.

Clinical Adjustment of the Occlusion, March 14 to 16, 1960.

Tooth and Denture Base Esthetics, March 21 to 23, 1960.

Full Denture Implants, March 28 to April 1, 1960.

A Special Participation Course in Periodontology, April 25 to 29, 1960.

Special Postgraduate Refresher Course in Prosthetics for the Periodontal Patient, May 9 to 12, 1960.

Applications are now being accepted for two Research Fellowships in Oral Pathology and Periodontology for the school year beginning September, 1960.

Complete Denture Prosthesis, June 6 to 10, 1960.

For further information and application, write to Director of Graduate and Postgraduate Studies, Tufts University School of Dental Medicine, 136 Harrison Ave., Boston, Mass.

The University of Washington, School of Dentistry, announces a new Graduate Program leading to a Master of Science degree. The following courses are available to properly qualified applicants: Fixed Partial Dentures, Operative Dentistry, Oral Pathology, Oral Surgery, Orthodontics, Pedodontics, Periodontics-Endodontics, and Prosthodontics.

For further information and application, write to Dr. Saul Schluger, Director, Graduate Dental Education, University of Washington, School of Dentistry, Seattle 5, Wash.

The First District Dental Society, a Component of the Dental Society of the State of New York and the American Dental Association, announces the following seminars in Prosthodontics to be given at the Hotel Statler Hilton:

Removable Partial Prosthesis With Precision Internal Attachments, Dec. 2, 1959.

Removable Precision Bridge Techniques, Dec. 15 to 19, 1959.

Present Day Concepts and Techniques in Crown and Bridge and Partial Denture Construction, Jan. 13, 1960.

Partial Denture Design, Jan. 13, 1960.

Complete Mouth Reconstruction Through Crown and Bridge Prosthodontics, Jan. 20 to 22, 1960.

The Complete Denture Setup, Wednesdays, March 2 and 9, 1960.

A bulletin describing all courses will be mailed on request by Dr. Maxwell A. Heckler, Supervisor, Postgraduate Department, First District Dental Society, Hotel Statler Hilton, New York 1, N. Y.

The Dental and Oral Surgery Service of The Mount Sinai Hospital in New York City announces that it is accepting applications for internship and residency for the calendar year beginning July, 1960. Application should be made as soon as possible, since selections are generally made in December.

For further information and application, write to Dr. Max Fuchs, Assistant Director, The Mount Sinai Hospital, 11 East 100th St., New York 29, N. Y.

The Department of Stomatology, Division of Graduate Studies, School of Medicine, Boston University, announces the following postgraduate courses:

Endodontics, Dr. Herbert Schilder, Nov. 30 to Dec. 4, 1959.

Oral Pathology for Oral Surgeons, Dr. Jack Bloom, Dr. Henry M. Goldman, and Dr. Kurt Thoma, Jan. 11 to 16, 1960.

Removable Partial Denture Prosthesis, Dr. David J. Baraban, Jan. 21 to 23, 1960.

For further information and application, write to Director of Postgraduate Studies, Department of Stomatology, Massachusetts Memorial Hospitals, 750 Harrison Ave., Boston 18, Mass.

The Veterans Administration, Medical Teaching Group Hospital, Memphis, Tennessee, announces that one rotating dental internship and one residency in Prosthodontics will be available for the year beginning July 1, 1960.

Information and application forms may be obtained from the Chief, Dental Service, Veterans Administration, Medical Teaching Group Hospital, Park Ave. and Getwell St., Memphis 15, Tenn.

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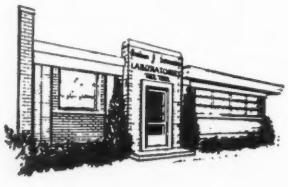

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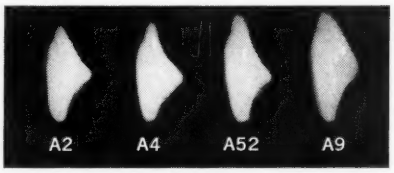
Meeting	No. of Participants	No. of Correct	% Correct
Boston	138	11	8.0
Buffalo	112	14	12.5
Toronto	104	13	12.5
TOTAL	354	38	10.7

Dura-Blend detectability test results. Full details may be secured by requesting Reprint DB 1.

(2) 28% laid specific emphasis on advantages derived from *the three new shades*. Previous study had shown the augmented Dura-Blend shade guide capable of yielding first choice in match to natural teeth 44% more often than any other of the shade guides tested.



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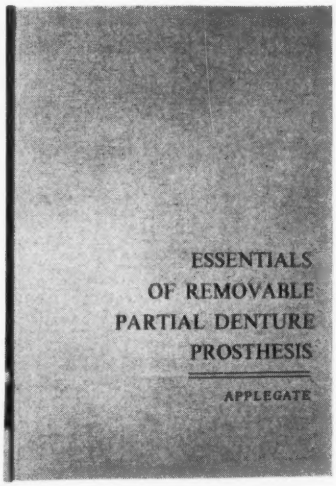

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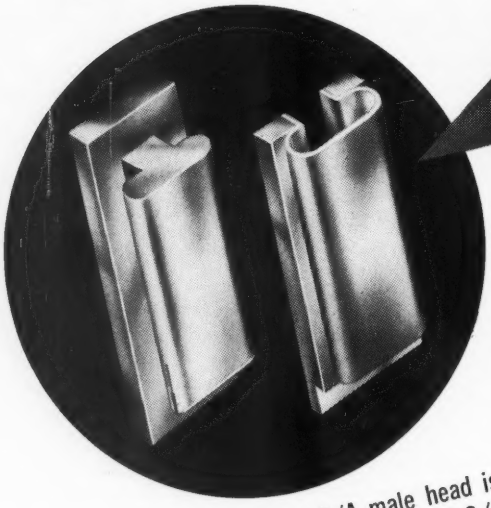

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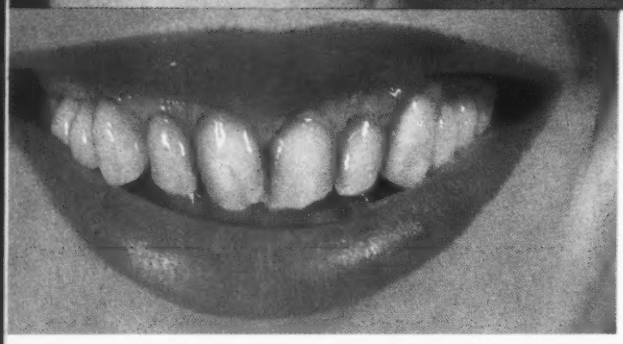

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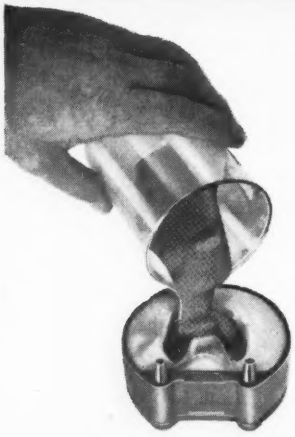

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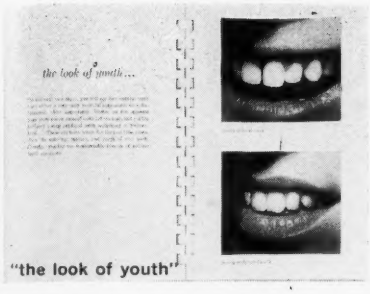

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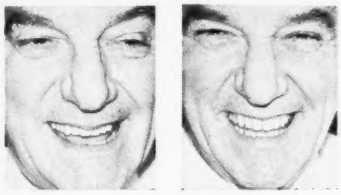
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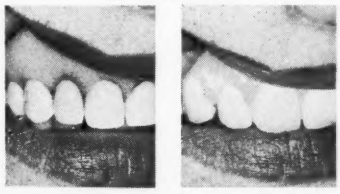
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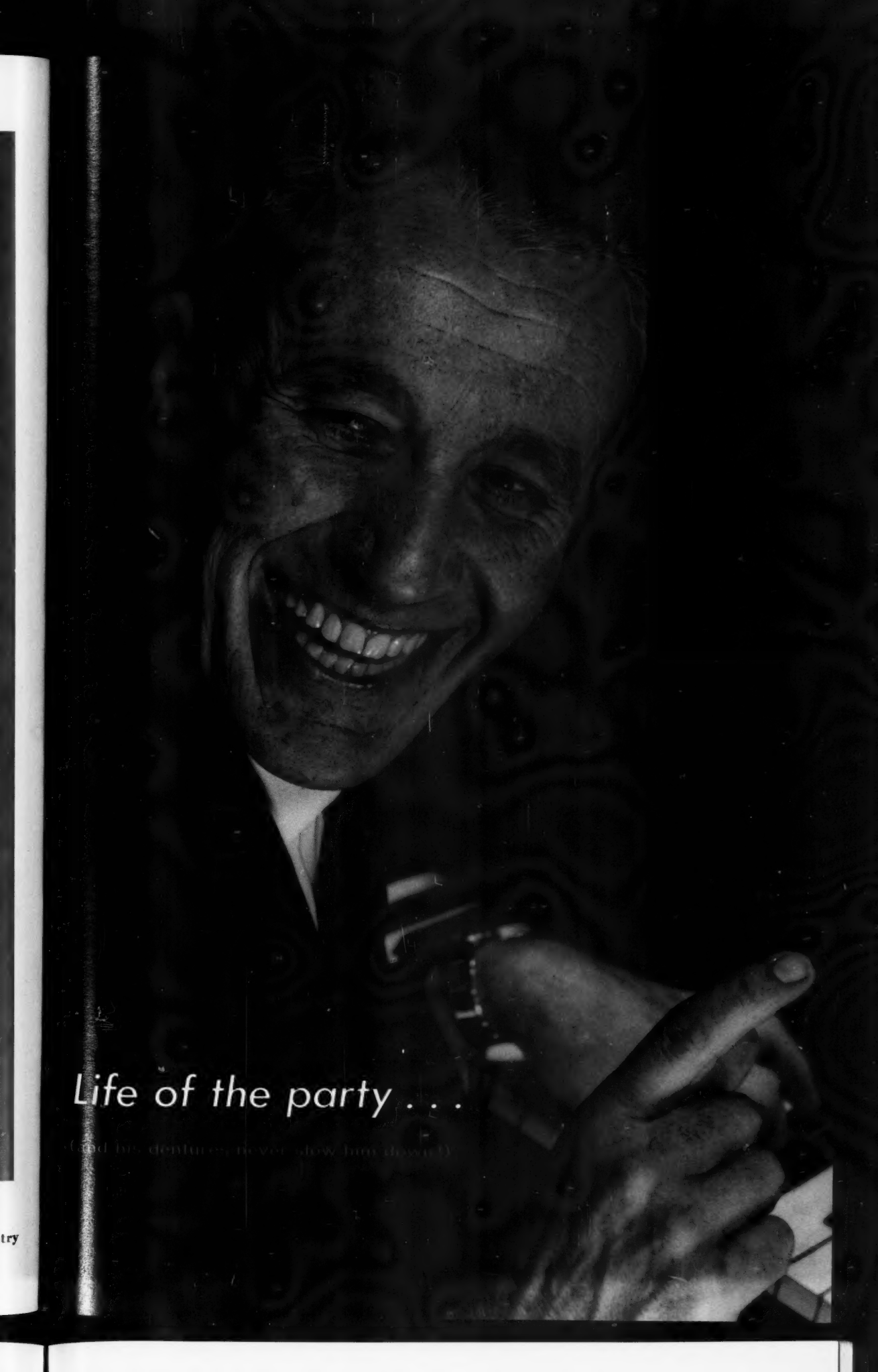
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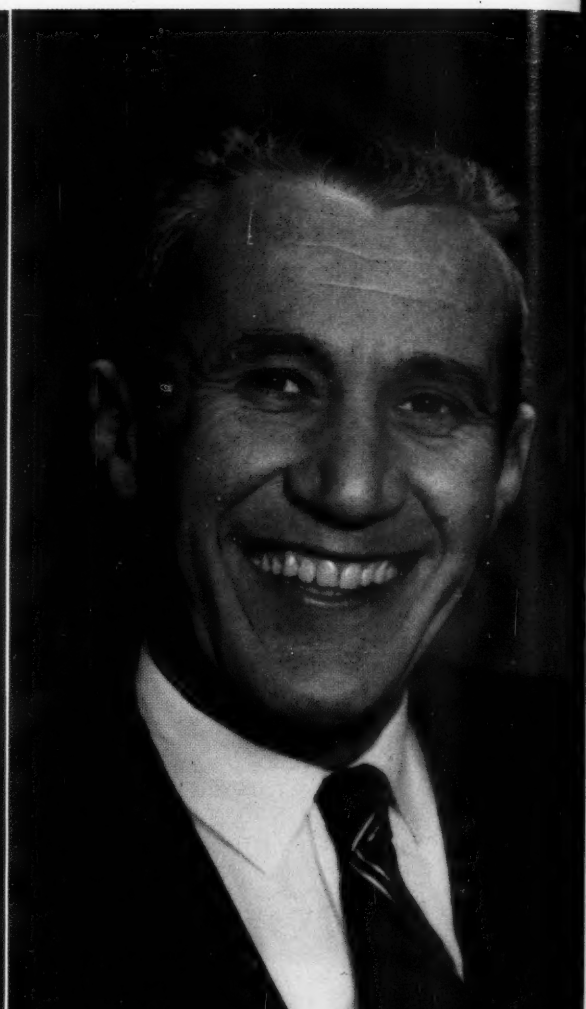

THE TRUBYTE BIOFORM ESTHETIC DENTURE

Compare the two photographs above. In the photo at left, the patient is wearing his original, conventional-style denture. In the photo at right, the patient is wearing his individualized Trubyte Bioform Esthetic Denture. In this lifelike restoration, notice the simulation of tooth abrasion and discoloration which are natural for a patient of this age . . . but more important, notice the over-all adherence to the Trubyte Bioform System of *Four Harmonies*. . . .

In the conventional denture, the teeth are too white, too small and too evenly arranged to really "live in the mouth".

In this Trubyte Bioform Esthetic Denture, the teeth have been selected, characterized and arranged to harmonize with the individual requirements of this patient.

HARMONY OF FORM

In an Esthetic Denture, there is harmony of face form and tooth form. In this case, the patient's outline face form is basically Square-Tapering . . . indicating selection of vigorous Trubyte Bioform *Square-Tapering* teeth.

HARMONY OF SIZE

The Trubyte Tooth Indicator was used to determine the size of the central teeth. This instrument (which is based upon the accepted Bio-Metric ratio of 16 to 1, face-size to tooth-size) indicated a tooth 9½ millimeters wide and 12 millimeters in length . . . therefore Square-Tapering mould No. 21J was selected.

HARMONY OF COLOR

The patient's age and facial coloring suggested tooth shades of strong yellow pigmentation, characterized by simulated natural staining.

HARMONY OF ARRANGEMENT

The basic arrangement of the teeth is tapering, modified by the square to provide width between the cuspids. It is slightly asymmetrical, in harmony with the greater dominance of the right side of the face. Note the prominence of the right lateral and cuspid, and the softening effect created on the left side by mesial-distal rotation. The teeth have also been ground, shaped and characterized individually.

Essential to finest esthetic results . . .

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BIOFORM® TEETH

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Enables you to verify your mould selection immediately when your patient is in the chair; the unique 7-drawer design facilitates selection of teeth which harmonize with the patient's face form; contains all the available upper and lower anterior moulds of Trubyte Bioform Teeth.

TRUBYTE BIOFORM SHADE SELECTOR ASSORTMENT

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TRUBYTE TOOTH INDICATOR

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ESTHETICS AND PATIENT EDUCATION

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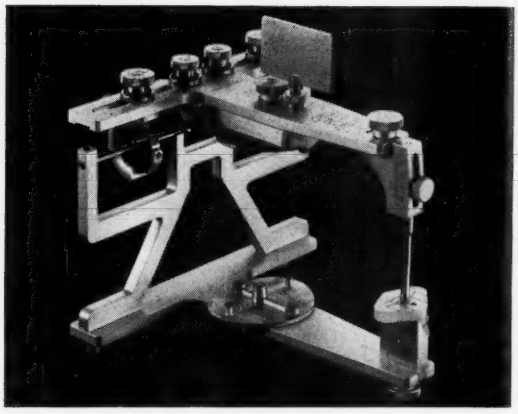

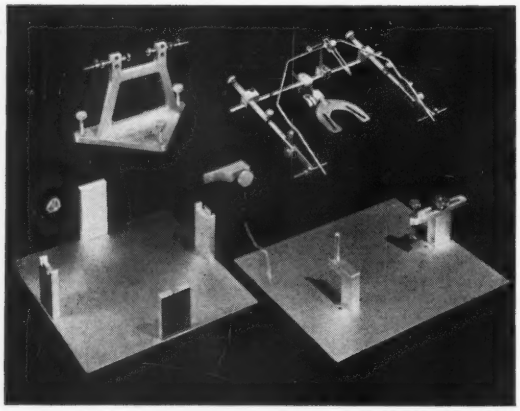

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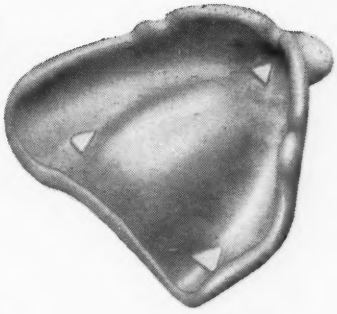

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Positioning the Ney Chayes attachment

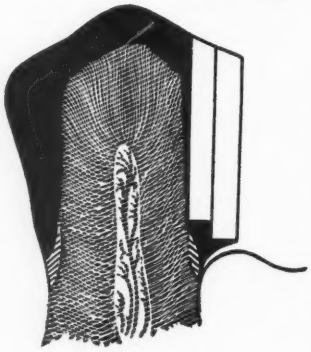

FIG. 1

Proper placement of the recess which is prepared in the abutment tooth to receive the internal frictional attachment is achieved by careful preliminary planning on the study model.

In figure 1, the recess has not been made deep enough to accommodate the attachment within the normal contour of the tooth. A gingival shelf is created which is unhygienic and destructive to the investing tissue. The mesio-distal dimension is also increased which results in unfavorable leverage on the abutment tooth.

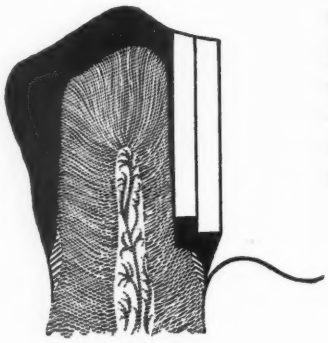

FIG. 2

Figure 2 illustrates the correct placement of the attachment within the confines of the abutment tooth, thus allowing enough room for the development of proper tooth contour.

(Prepared under the direction of competent dental authority.)

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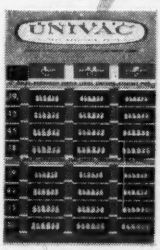

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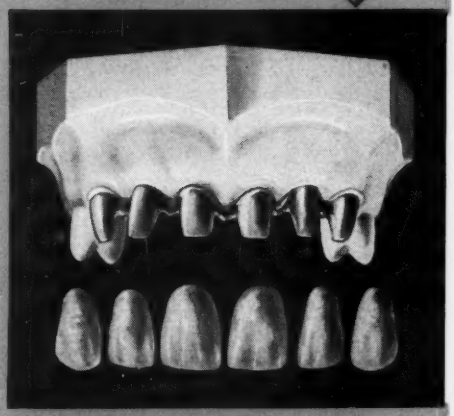

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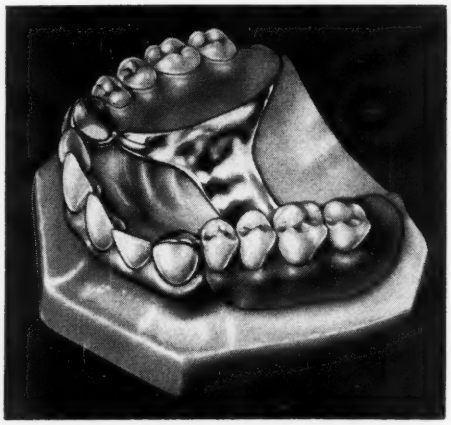

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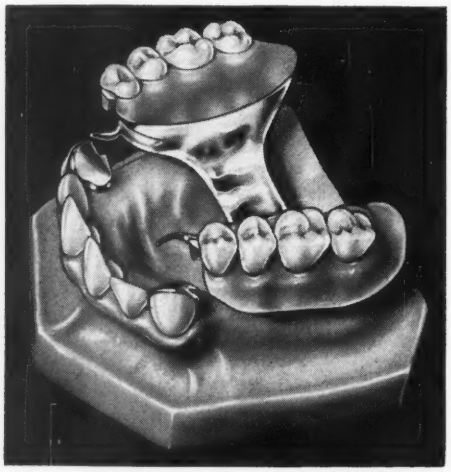

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Postgraduate Lecturer and Clinician, Charter Member of the American Academy of Crown and Bridge Prosthodontics

and ALBERT J. KAZIS, D.M.D.
Visiting Instructor in Prosthetic Dentistry (Crown and Bridge), School of Dental Medicine, Tufts University, Boston, Massachusetts

LONG considered an important part of modern dentistry, complete mouth rehabilitation has made great developmental strides in both diagnosis and treatment. In this book the authors present a practical working text based on the technics and procedures they employ in practice, on their scientific studies of the subject, and on continuing extensive research. Dr. Harry Kazis is a noted pioneer in this field.

The subject is considered under three main heads. Theories and basic principles fundamental to mouth rehabilitation are presented first. Chapters on functional aspects, physiological rest position, vertical dimension, and occlusion lead into an evaluation of periodontal considerations in crown and bridge prosthodontics. This is followed by methods and technics used by the authors in the diagnosis, treatment planning and treatment of the conditions described in Part I. Twenty-five case reports are typical of the mutilated bite anomaly cases which may be encountered in practice. The final section is devoted to discussions of the operative and technical considerations in crown and bridge prosthodontics, with emphasis on anesthetic, operative and technical procedures. The final chapter presents a detailed picture story of the technical procedures involved in an extensive mouth rehabilitation case; and concludes with a pictorial descriptive technic for the construction of a movable-removable precision attachment partial denture.

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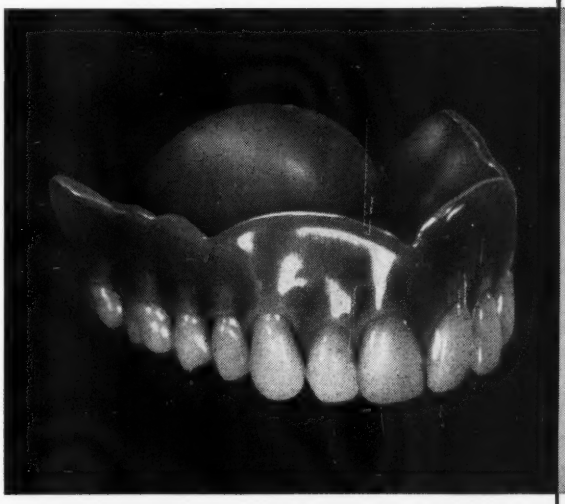

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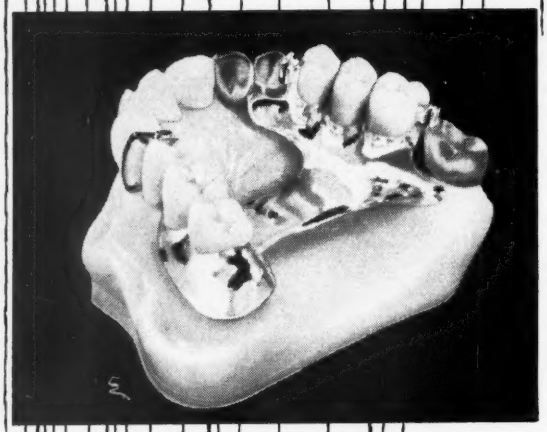

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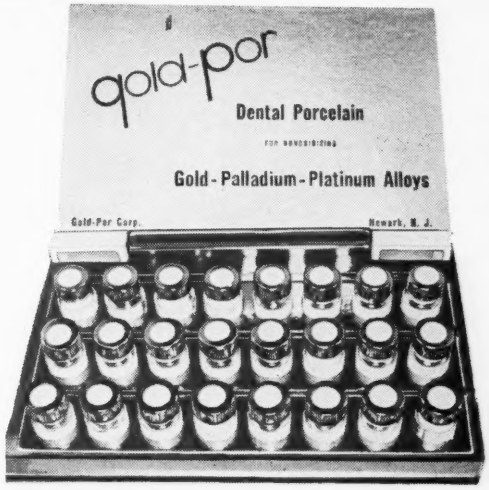

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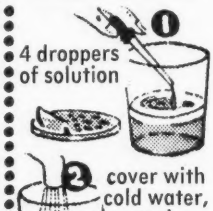

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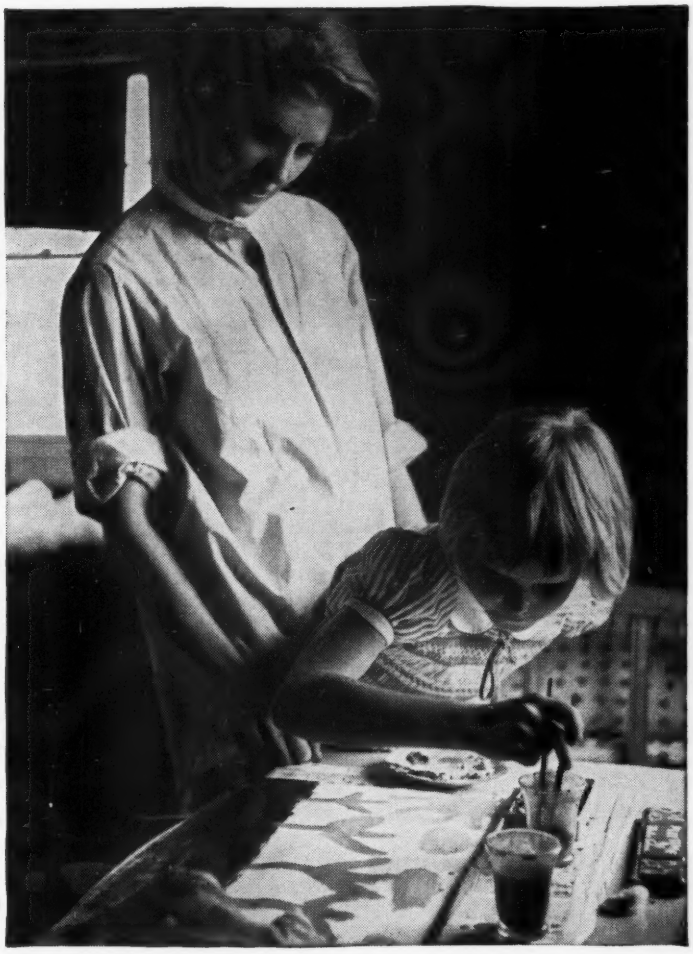

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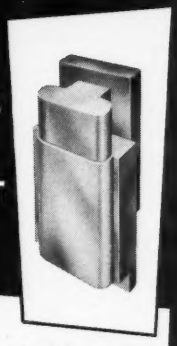

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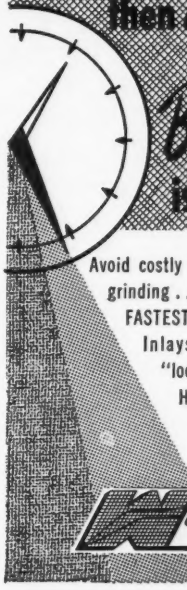

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ON

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WITH SPECIFIC EMPHASIS ON DENTAL CARIES AND PERIODONTAL DISEASES

Edited By

JOSEPH C. MUHLER, D.D.S., Ph.D., Associate Professor, School of Dentistry and Department of Chemistry, Indiana University, Bloomington, Indiana

and

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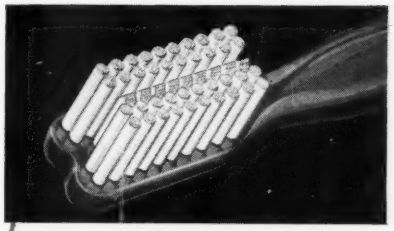

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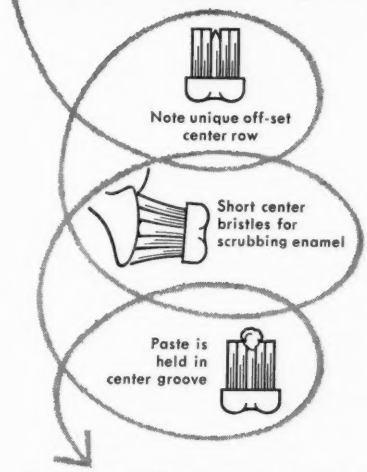

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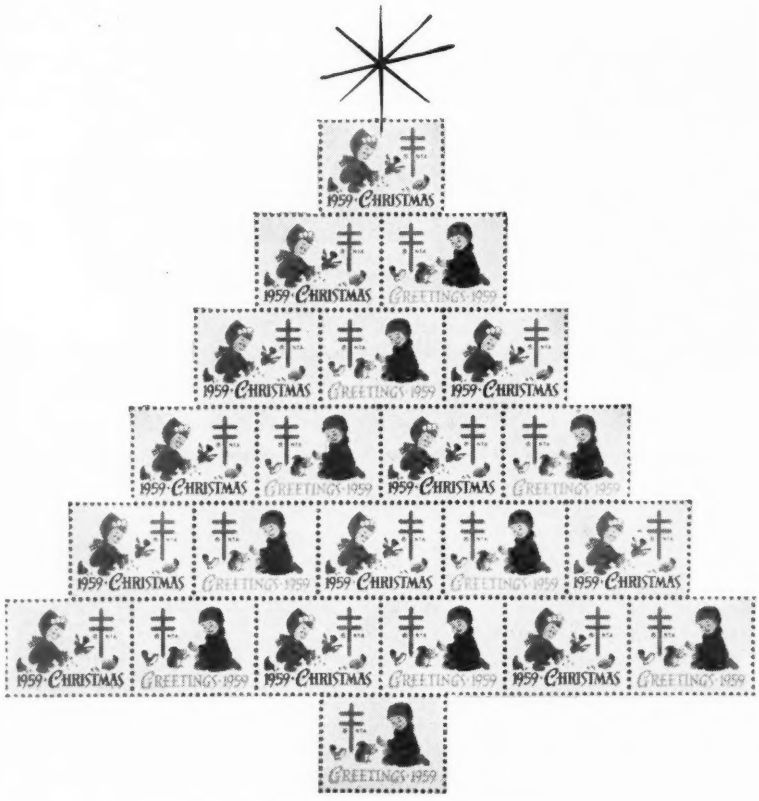

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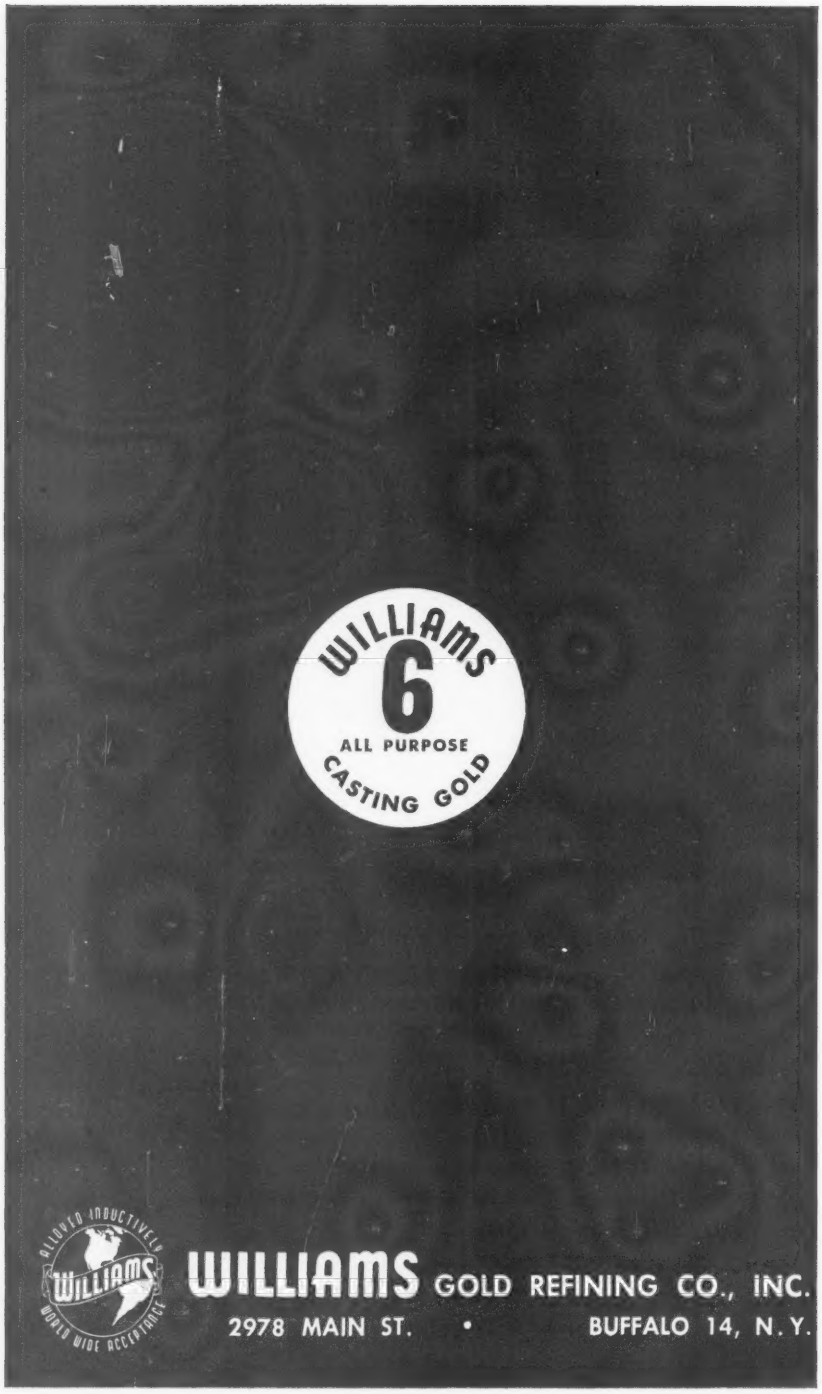
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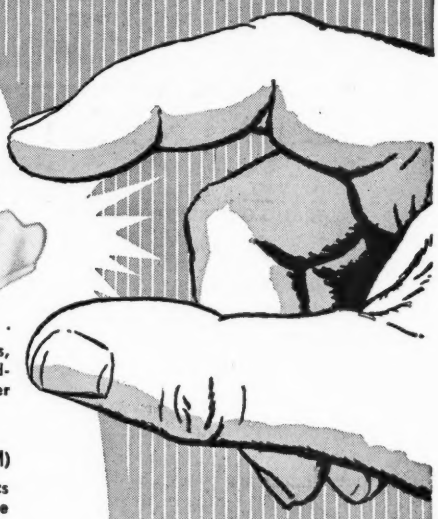

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